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THREE-CUE HELICOPTER FLIGHT DIRECTOR EVALUATION.(U)

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THREE-CUE HELICOPTER FLIGHT DIRECTOR EVALUATION,

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Preface

This report covers the work accomplished during an inflight investigation concerning the evaluation of the changes in pilot performance, control activity and biochemical changes while flying with various display configurations of a helicopter Three-Cue Flight Director System.

Flying activities were conducted by pilots assigned to the USAF Instrument Flight Center, Research and Development Division (USAFIFC/RD), Randolph Air Force Base, Texas. Flights were conducted in the ~~USAFIFC's~~ TH-1F helicopter. The subject pilots participating in the study consisted of both ~~USAFIFC~~ Instructor Pilots and pilots attending the ~~USAFIFC~~ Instrument Pilot Instructor School (IPIS).

The Project Officer was Major William E. Clark, Jr., Project Pilots were Captain Russell J. Spahr and Captain Richard G. Gasparian. Human factors support was provided by Mr. Gerald C. Armstrong. The USAF School of Aerospace Medicine (USAFSAM) provided both technical assistance and human factors support. USAFSAM project officers were Captain Steven F. Gray and First Lieutenant Donald L. Makalous.

Data reduction was accomplished by the Air Training Command Data Automation Division. Appreciation is expressed to SSgt William L. Snyder and Mr. James L. Elliott for their efforts in the data reduction process.

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TABLE OF CONTENTS

Page

LIST OF FIGURES

LIST OF TABLES

ABBREVIATIONS

AAU-19/A	Counter-Drum-Pointer Altimeter
ADI	Attitude Director Indicator
AFM	Air Force Manual
ALT	Altimeter
ANOVA	Analysis of Variance
ATT	Attitude
Bio/Med	Biomedical
BPM	Beats per minute
CFI	Control Frequency Index
CMD	Command
DH	Decision Height
DME	Distance Measurement
DOF	Degrees of Freedom
E	Epinepherine
ECG	Electrocardiogram
F	Variance-Ratio Distribution
F/D	Flight Director
FD109	Flight Director System
FPA	Flight Path Angle
fpm	Feet per minute
GA	Go-around
GS	Glide Slope
HCl	Hydrocholoric
Hdg Sel	Heading Select
Hiqual	High Qualified
$\overline{\text{Hiqual}}$	Not Highly Qualified
H/R	Heart Rate
HSI	Horizontal Situation Indicator
HUD	Heads-up Display
ILS	Instrument Landing System
IMC	Instrument Meteorological conditions
J-Tec	Precision Airspeed System
K	potassium
kts	Knots
LOC	Localizer
M	Mean
Na	Sodium
Natel	Demodulator Assembly
Nav	Navigation
ND	No Data
NE	Norepinepherine
N/L	Nav/Loc (Navigation/Localizer)
OHCS	Hydroxycorticosteriods
PAR	performance activity ratio
PEA	prismatic electromechanical annunciator
P=A/S	pitch equals airspeed
p=G/S	pitch equals groundspeed
PiFax-H	Pilot Factors for Helicopter Program
SAS	Stability Augmentation System
SD	Standard Deviation
R	Radial

Sec	Second
SN	Serial Number
TACAN	Tactical Air Navigation
Th-1F	Bell Helicopter (Huey)
USAFIFC	United States Air Force Instrument Flight Center
IFC/RD	Instrument Flight Center, Research and Development Division
USAFSAM	United States Air Force School of Aerospace Medicine
VHF	Very High Frequency
VMC	Visual Meterological Conditions
VOR	VHF ominirange
VVI	Vertical Velocity Indicator

USAF INSTRUMENT FLIGHT CENTER
Randolph AFB TX 78148

USAFIFC TR 77-3 July 1977

THREE-CUE HELICOPTER FLIGHT DIRECTOR EVALUATION

INTRODUCTION

At present, the Pilot Factors for Helicopter (PIFAX-H) Program has progressed through four distinct, yet interrelated, phases. These phases were (1) Pre-Experimental (Baseline) Flying, (2) Refined Displays Evaluation, (3) Stability Augmentation Evaluation, and (4) Three-Cue Flight Director Evaluation. During these interrelated phases of the PIFAX-H program, helicopter instrument instructors generated pilot performance and control activity data by flying basic instrument maneuvers under simulated instrument (hooded) conditions.

In the Pre-Experimental Flying Phase, in-flight data collection procedures were implemented and computerized data reduction techniques were developed. As a result of the pre-experimental flying, several control-display deficiencies were identified and specific areas noted in which improvements were required. In addition, the experienced helicopter pilots contributed many mission oriented recommendations for improving the instrument flight capabilities of the standard light helicopter.

The second phase of the PIFAX-H program concentrated primarily on display improvements. A refined ADI, HSI, and supporting displays were evaluated. The subjective data provided by the helicopter pilots indicated pilot acceptance of the display improvements. The analysis of the objective data did not reveal a significant increase in performance and no decrease in control activity was noted when flying with the display improvements. Based upon the experience with the refined displays, the subject pilots recommended control stabilization advancement, concurrent with display improvements, to increase performance and reduce control activity.

The third phase of the program investigated control stabilization in conjunction with the display refinements. A yaw axis stability augmentation system (SAS) with a heading hold mode and turn coordination capability was installed for use as a test item. The subject pilots flew basic instrument maneuvers, both, with the Yaw SAS engaged and with the Yaw SAS disengaged. Performance and activity data, with and without stability augmentation, was obtained for a comparative analysis. When flying constant heading maneuvers with the Yaw SAS engaged in the heading hold mode, all pilots reported a noticeable decrease in workload. Several pilots specifically commented on gaining increased performance during turning maneuvers with the Yaw SAS turn coordination engaged.

The fourth phase centered on a helicopter flight director that provided integrated functional commands displayed on the ADI. The functional commands were evaluated during basic instrument maneuvers and terminal area navigation/approach maneuvering in both Two-cue (pitch and roll command) and Three-cue modes.

SECTION I

Description of Test Vehicle

The evaluation was conducted in USAFIFC/RD, TH-1F helicopter (SN 66-1250). The TH-1F is representative of the basic, light-to-medium class unaugumented helicopter. The aircraft was specially modified to accomodate evaluations of the refined control-display elements in the overall PIFAX-H program. A brief description of the modified instrument panel major components is presented in the following paragraphs.

PILOT'S ATTITUDE DIRECTOR INDICATOR (ADI)

The pilot's attitude director indicator was located on the pilot's section of the instrument panel (figure 1). This instrument has been modified to display the flight parameters peculiar to helicopters rather than those of fixed-wing aircraft. See figure 2 for ADI displays.

The ADI presented aircraft attitude and flight information on a symbolic 3-dimensional, forward-view display. Aircraft attitude was displayed by the relationship of a stationary aircraft symbol with respect to a horizon line. The horizon was presented on a tape that was servo-driven in both roll and pitch. The tape had graduated pitch markings (up and down) and was colored to represent the sky (blue) above and ground (brown) below the horizon line, respectively. Pitch and roll scale was approximately double that of a conventional attitude indicator.

Deviation from the glide slope beam center was indicated by a glide slope deviation pointer on the right side of the instrument. The glide slope pointer operated only when the navigation receiver was tuned to a localizer frequency and the nav selector switch was in the VOR/ILS position and the MARKER switch was ON. In the TACAN and VOR modes, the glide slope pointer and flag (GS) were in view. The (GS) flag covered the pointer when glide slope signals were not present, or when they were not reliable.

A pad symbol, located in the lower portion of the display moved vertically to indicate radio altitude 0 to 200 feet and laterally to indicate lateral deviation from the beam in the ILS mode. In response to radar altimeter signals, the pad symbol rose upwards and indicated 0 feet when immediately under the aircraft symbol. When in the VOR/ILS mode and tuned to a VOR frequency, or in the TACAN mode, the pad symbol was biased out of view.

A flight path angle tape was installed on the left side of the indicator and was read against a fixed index. The upper half of the tape was blue, and the lower half was brown. Inputs driving this function were from the Flight Path Angle Computer.

FLIGHT PATH ANGLE/RADAR ALTITUDE DISPLAY PANEL (figure 3)

Mounted immediately above the ADI was a bezel containing Selected Flight Path Angle (+ 19 thru -19°) and Radar Altitude. The flight path angle (FPA) display used a two-digit display preceeded by a plus (+) for positive FPAs and a minus (-) for negative FPAs. The three-digit Radar Altitude display was incremented in the following format and blinked off between each display change:

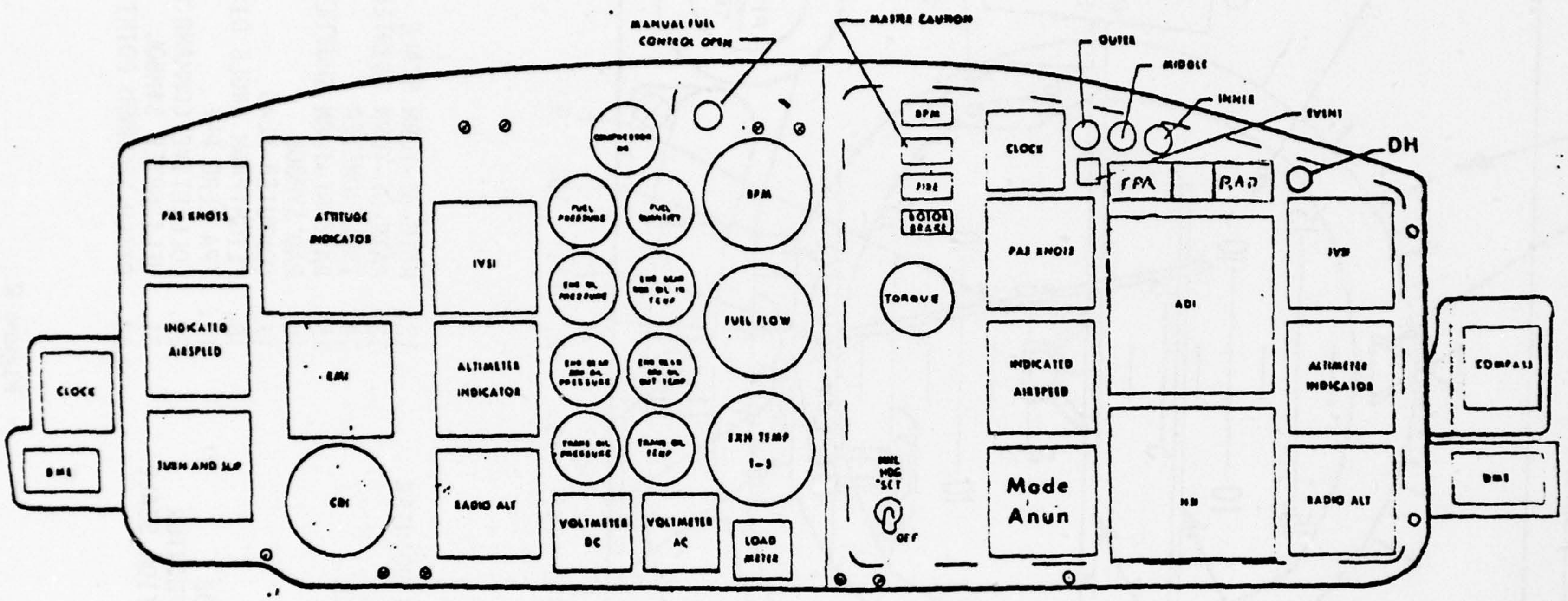
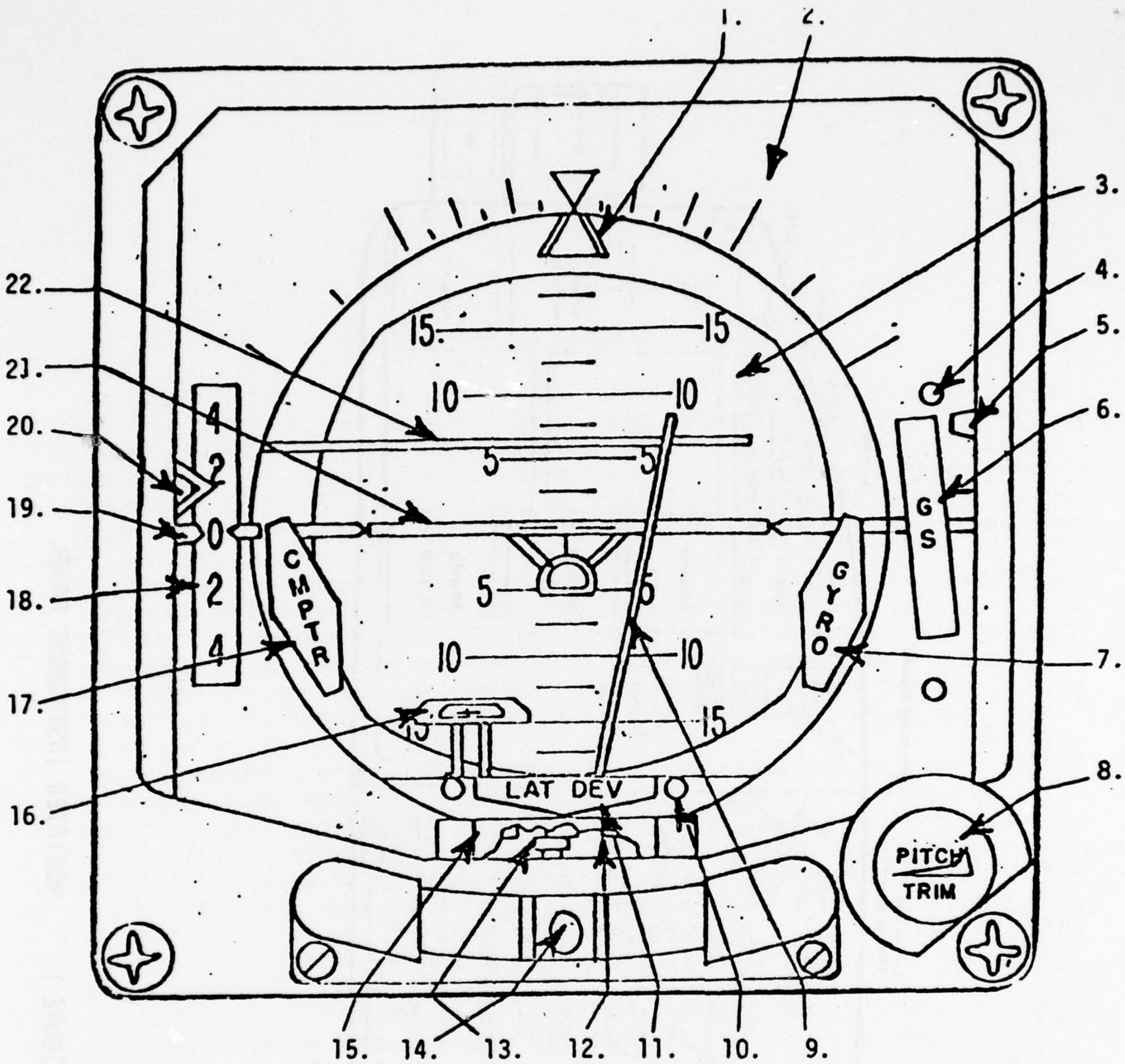


FIGURE 1 MODIFIED INSTRUMENT PANEL



1.	ROLL ATT INDEX POINTER	12.	RATE-OF-TURN SCALE
2.	ROLL ATT SCALE	13.	RATE-OF-TURN POINTER
3.	PITCH ATT SCALE	14.	INCLINOMETER
4.	GS SCALE	15.	RATE-OF-TURN SHUTTER
5.	GS POINTER	16.	PAD SYMBOL
6.	GS FLAG	17.	COMPUTER FLAG
7.	GYRO FLAG	18.	FLIGHTPATH ANGLE DISPLAY
8.	PITCH TRIM KNOB	19.	FPA ZERO REF
9.	ROLL COMMAND POINTER	20.	COLLECTIVE COMMAND POINTER
10.	LATERAL DEVIATION SCALE	21.	HELICOPTER SYMBOL
11.	LAT DEV FLAG	22.	PITCH COMMAND POINTER

Figure 2

Altitude Range	Display Increment
0' - 10'	1'
10' - 50'	5'
50' - 100'	10'
100' - 300'	20'
300' - 1000'	50'
Above 1000'	Blank

PILOT'S HORIZONTAL SITUATION INDICATOR (HSI)

The pilot's horizontal situation indicator, located on the pilot's section of the instrument panel, displays the horizontal position of the aircraft with respect to the selected navigation aid. See Figure 4 for HSI displays.

RADIO ALTIMETER SYSTEM, ALT-50

The ALT-50 Radio Altimeter System provides the pilot with dependable and accurate visual altitude indications during the critical approach phase of the flight (2000 feet to touchdown). The system alerted the pilot when the aircraft descended to the preselected decision height point by illuminating the light on the upper left of the indicator and the light (DH) above the ADI. The system also supplied altitude information to the flight director (ADI) system during the approach phase.

INSTANTANEOUS VERTICAL SPEED INDICATOR

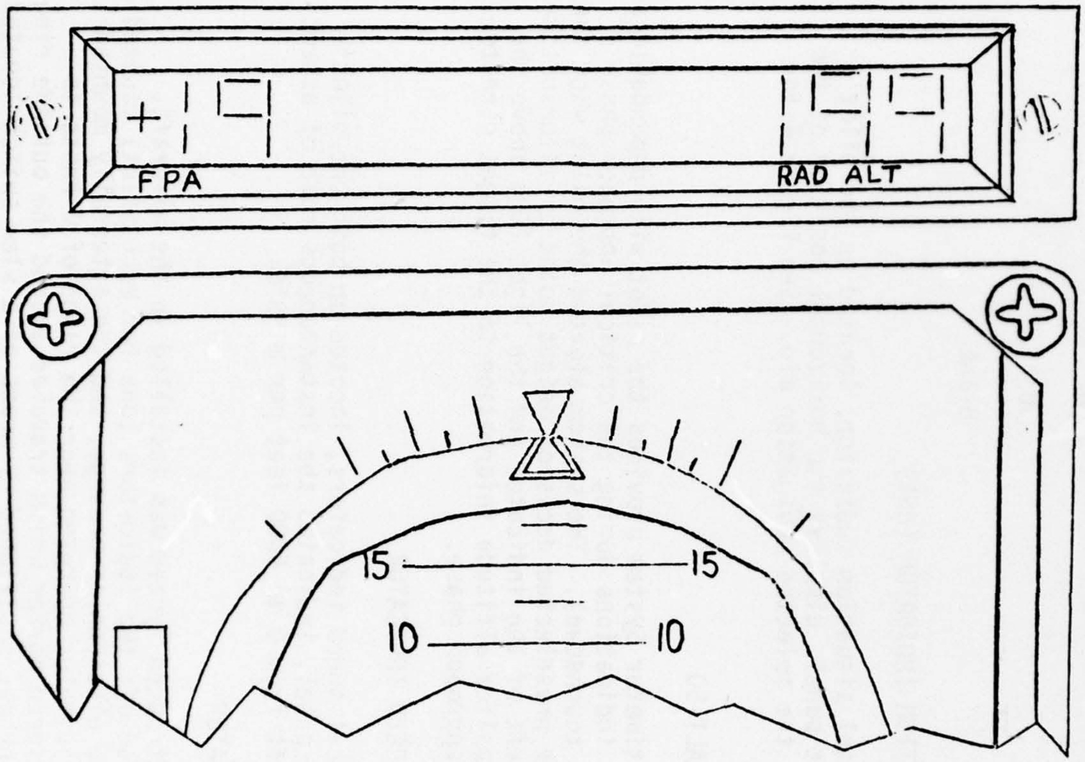
Instantaneous vertical speed indicators, located on both the pilot's and copilot's instrument panel, indicated the instantaneous rate of ascent or descent of the aircraft from 0 to 6000 feet per minute.

PRECISION AIRSPEED INDICATOR

A J-TEC Precision Airspeed System was installed in the aircraft. The installation consisted of; two indicators (one for each pilot) mounted on the instrument panel, the electronics package, and the externally mounted airspeed sensor. Each indicator operated over the range of 0 knots to 160 knots and had an airspeed marker which traveled around the outside ring of the indicator. The marker was positioned by means of a slew switch located on the pilot's cyclic grip (figure 5).

EVENT MARKER LIGHT

An EVENT marker light had been installed in the pilot's instrument panel. This light was activated whenever the EVENT marker switch on the instrumentation rack was actuated or the button on either pilot's cyclic stick was depressed. Actuating the EVENT light also sent a signal to the data acquisition tape.



SELECTED FLIGHT PATH ANGLE/RADAR ALTITUDE DISPLAY

Figure 3

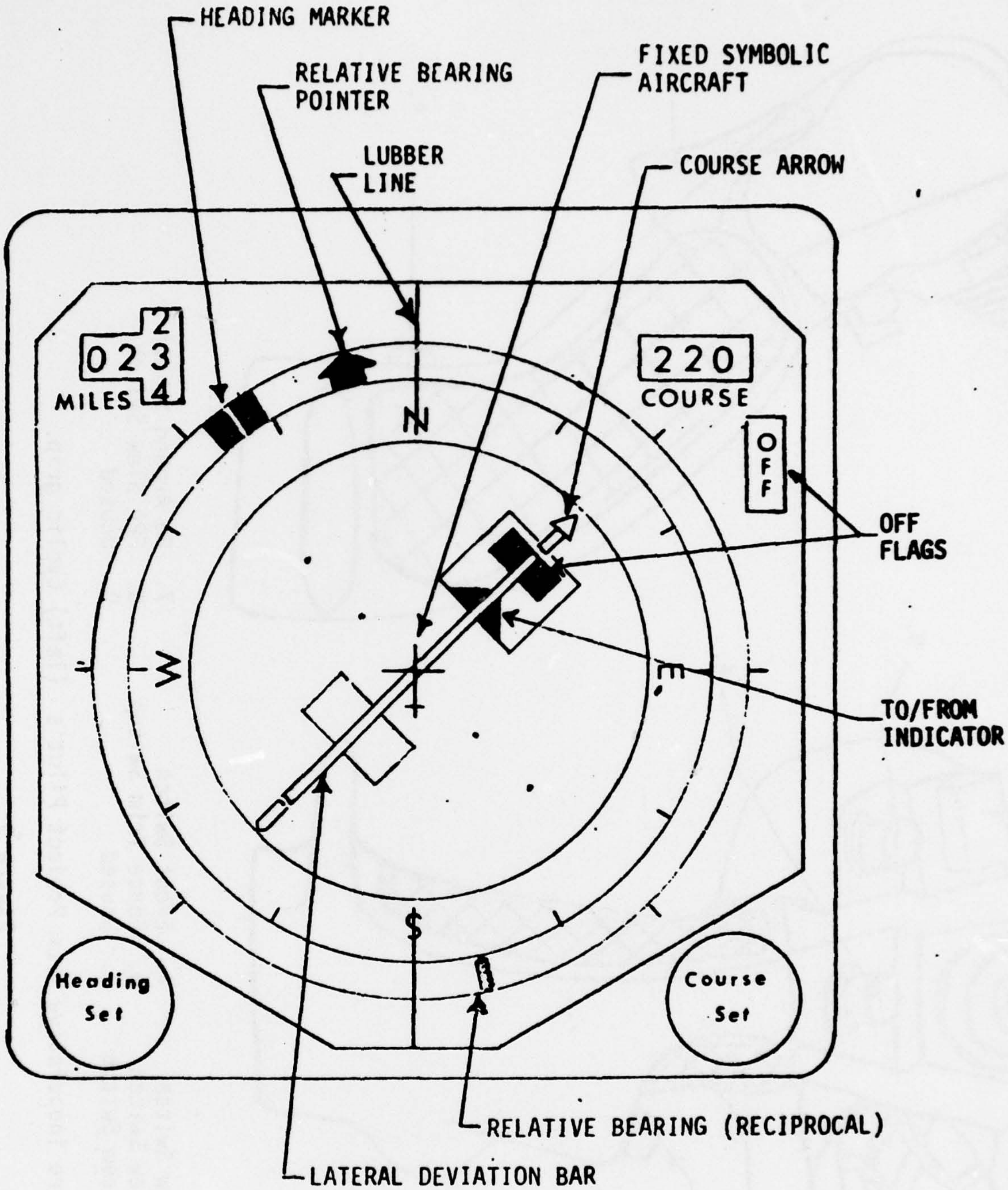
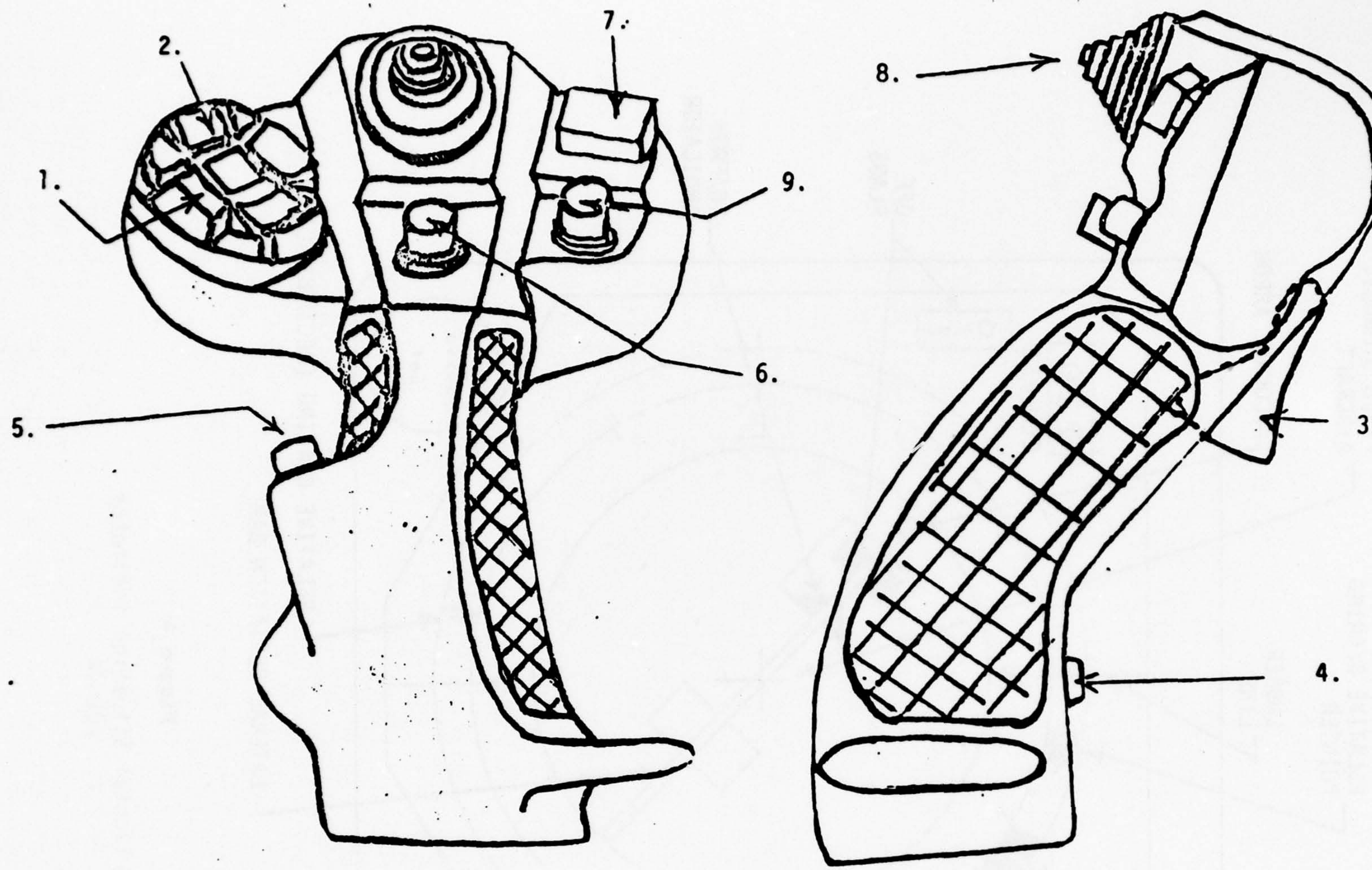


Figure 4

Horizontal Situation Indicator
AQU-4A



1. Heading Slew Switch
2. Airspeed Slew Switch
3. Radio/Intercom Switch
4. Event Switch
5. Force Trim Switch
6. Unused
7. Go Around Switch
8. FPA Slew Switch
9. Unused

NOTE: Items 7&8 are inoperative from Project Pilot's (left) Cyclic grip.

Figure 5
PILOTS' CYCLIC GRIP

AAU-19/A ALTIMETER

An AAU-19/A Counter-Drum-Pointer Altimeter was located on the subject pilot's panel and provided the pilot with the same information as the conventional 3-pointer system it replaced. Additionally, the AAU-19/A provided altitude inputs to the Flight Director System.

INSTRUMENTATION RECORDER SYSTEM DESCRIPTION

An instrumentation recording system rack was installed in the cargo-passenger compartment just aft of the pilot's station. An operator's seat was installed aft of the project pilot's (left seat) station facing the instrumentation rack.

The rack contained a digital incremental magnetic recorder, a 10-channel Natel demodulator assembly and a time code generator. This system enabled the in-flight recording of up to 32 control-display parameters. Each channel was sampled at a rate of five times per second.

Position sensors had been mounted in the aircraft and connected to the primary flight control system. The control position sensors and display performance parameters were electrically connected to the recording system. The versatility of the recording/sensor system allows "tailoring" for each project. The list of parameters used for the Flight Director Evaluation is contained in Section II.

DESCRIPTION OF TEST ITEM

FLIGHT DIRECTOR SYSTEM

The three-cue helicopter flight director currently installed, is based on a Collins FD109 system. Extensive modification to the basic system has resulted in changes to the original fixed-wing displays, capture logic, command functions, and thus provides a system suited to helicopter instrument flight.

The major display components in the Flight Director are:

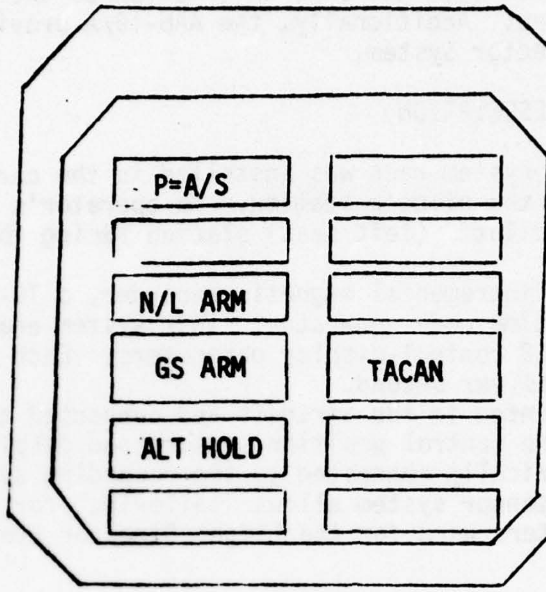
ADI*
HSI*
Cyclic Grip*
Mode Annunciator
Flight Director Control Panel
Mode Controller
*Basic description in previous section.

MODE ANNUNCIATOR

The mode annunciator consists of 12 prismatic electromechanical annunciator (PEA) mechanisms (figure 6). Each annunciator is capable of displaying one or two messages. The messages are printed on two faces of a triangular bar and are brought into view by energizing solenoids. Only items associated with the flight director system are annunciated. The mode annunciator is located on the pilot's panel to the left of the HSI.

FLIGHT DIRECTOR MODE ANNUNCIATOR

SIDE 1.



SIDE 2.

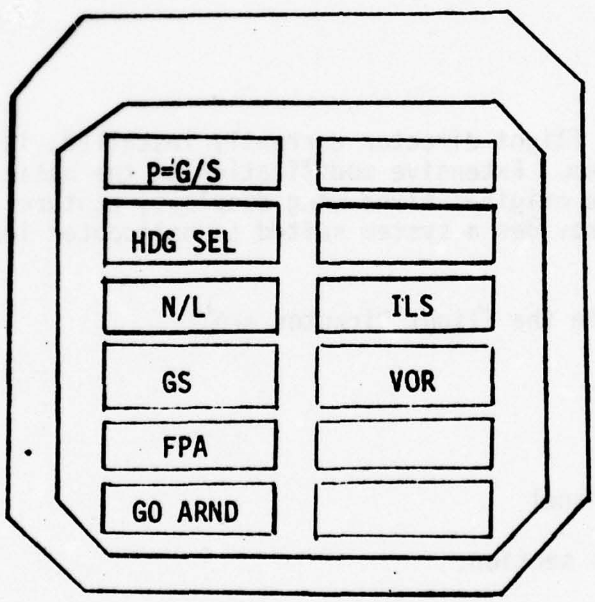


Figure 6

FLIGHT DIRECTOR CONTROL PANEL

The flight director control panel (figure 7) is located just below the mode control on the center console. In addition to being the primary control panel for the flight director it also houses the roll trim knob for the ADI.

The Two-cue/Three-cue switch provides a means of biasing the collective command out of view and thus reverts the flight director to a Two-cue system.

The Three-cue mode logic chart (figure 8) provides a brief description of each mode of operation. An operational description (by command) follows:

FLIGHT DIRECTOR OPERATION (THREE-CUE)

ROLL COMMAND

The roll command pointer (Item 9, figure 2) directs the pilot to turn to and maintain a selected heading or course.

Heading Mode: The pilot selects the desired heading by means of the heading slew switch (Item 1, figure 5) located on the pilot's cyclic grip. The roll command will then command up to a 15° angle of bank and roll out on the heading under the heading marker on the HSI (figure 4). HDG SEL appears on mode annunciator (figure 7) indicating that the roll command is responding to the heading located under the heading marker.

NAV/LOC Mode: The roll command will function as described above until the flight director computer switches to a capture mode. When the pilot switches to the NAV/LOC mode, a N/L ARM mode annunciator segment will appear. When the computer goes into a capture mode, the mode annunciator will remove the HDG Select segment and the N/L Arm segment will switch to a N/L segment. This indicates to the pilot that the heading marker is without affecting the roll command. This procedure is employed when setting up for a missed approach.

By being able to establish the original course intercept heading with the heading marker and then having the computer switch to capture at the appropriate distance from the course, an all-angle intercept capability is provided. The capture laws adjust for airspeed and intercept angle in order to provide a turn to on course at any combination of angle and airspeed. The pilot need only insure that he is not too close to course when setting up the intercept. If this is the case, he can either slow the aircraft, decrease intercept angle, or accept the resulting overshoot.

Once established on course (ILS, VOR, TACAN), the computer goes into a "track" mode which provides crosswind correction. This is done automatically and no mode annunciations are provided.

Approach Mode: The approach mode is very similar to the NAV/LOC mode with only changed gains and crosswind corrections being provided to compensate for increased sensitivity of NAV signals "close in." An "over the cone" operation is provided in both the NAV/LOC and Approach modes. This feature allows the pilot to fly through the station without "chasing" the bearing pointer. Once the aircraft is on the other side of the station and bearing has settled down, the roll command will direct the pilot to the course

FLIGHT DIRECTOR CONTROL PANEL

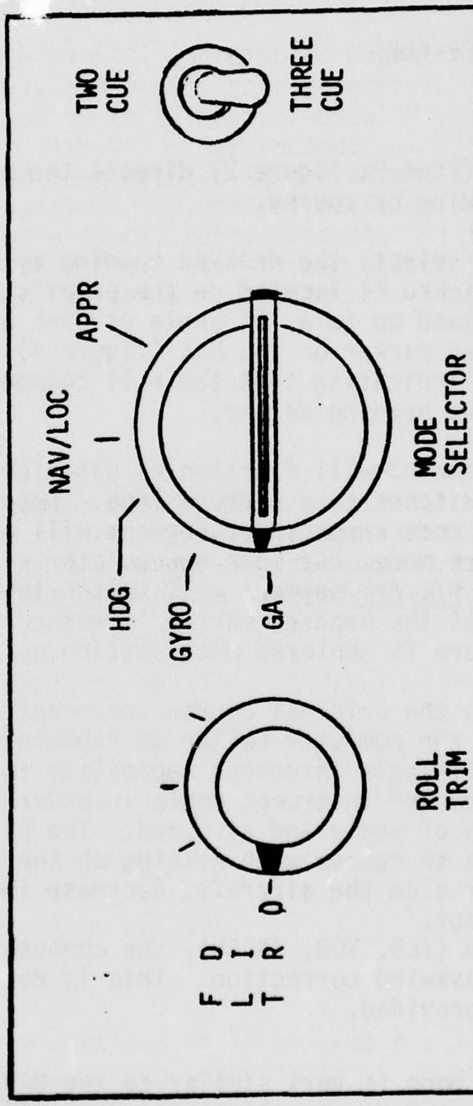


Figure 7.

THREE CUE FLIGHT DIRECTOR

	GYRO MODE	HEADING MODE	NAV/LOC MODE	APPROACH MODE	GO AROUND MODE
ROLL COMMAND	OUT OF	SELECTED HEADING	SELECTED HEADING UNTIL COURSE CAPTURE - THEN TURN ON TO SELECTED COURSE		SELECTED HEADING
PITCH COMMAND	VIEW	*SELECTED AIRSPEED			
COLLECTIVE COMMAND		*SELECTED FPA OR ALTITUDE HOLD		SELECTED FPA OR ALTITUDE HOLD UNTIL G.S. INTERCEPTION (ILS TUNED) - THEN GLIDE SLOPE	4° FPA CLIMB

*out of view when accelerating from zero to 30 knots precision airspeed and when decelerating thru 10 knots precision airspeed

Figure 8

set in the course window. Course changes over the station can be made up to thirty degrees without going back to the capture logic. If larger course changes are required, the capture and tracking process will be automatically engaged in the flight director computer.

Go-Around Mode: In the go-around mode, the roll command responds to the heading selected under the HSI heading marker. The pilot selects the go-around mode by either placing the flight director mode selector panel to go-around or by punching the go-around button on the pilot's cyclic grip (Item 7, figure 5).

PITCH COMMAND

The pitch command (Item 22, figure 2) will direct the pilot to decelerate, or accelerate, to and maintain the airspeed he has selected. The airspeed is selected by means of a slewable airspeed marker located on the outer ring of the precision airspeed indicator. This marker is slewed by depressing the "airspeed slew" switch (Item 2, figure 5) on the pilot's cyclic grip. Pressing the upper portion of the switch increases airspeed while pressing the lower portion of switch moves marker to a lower airspeed.

The pitch command operates in response to selected airspeed in all flight director modes.

Due to the lack of precise airspeed information, when accelerating from zero airspeed to 30 knots precision airspeed, the pitch command is biased out of view. Upon reaching 30 knots, the pitch command will direct the pilot to the airspeed he has selected. A similar situation occurs when decelerating through 10 knots precision airspeed.

A ten-degree pitch change is the maximum the pitch command will direct during accelerating or decelerating maneuvers.

COLLECTIVE COMMAND

The collective command (Item 20, figure 2) directs the pilot to maintain either a preselected flight-path angle (FPA), a barometric altitude, or intercept and maintain an ILS glide slope.

Desired FPA is selected by means of a slew switch located on the pilot's cyclic grip (Item 8, figure 5). Pushing the switch forward commands a lower FPA while pressing aft on the switch increases the FPA selected. The selected FPA is read out in the upper left corner of the FPA/RAD ALT displays. Raw data flight-path angle information is continuously displayed on an FPA tape located on left side of ADI display (Item 18, figure 2).

In order to engage the selected FPA, the pilot moves a switch located on the collective lever. When FPA is engaged, the mode annunciator will show a "FPA" segment, and the collective command will direct up or down collective to the preselected FPA. As in the case of the pitch command, low airspeed (accelerating from zero to 30 knots and decelerating below 10 knots) will cause the collective command to bias out of view when in Three-cue mode.

Altitude hold is engaged by the same switch used for FPA (located on pilot's collective lever). When switching to altitude hold, the "FPA" annunciator will change to "altitude hold."

Altitude hole is engaged by the pilot when he is at or passing through desired altitude. The collective command will then direct him to maintain that altitude. If he should get off altitude, the command will direct him back to that altitude.

Approach Mode: The collective command will also intercept and maintain an ILS glide slope as long as a good GS signal is received and mode controller is in "approach mode."

The capture is automatic and is evident when "GS Arm" annunciator changes to "GS" and "FPA" or "ALT HOLD" segments go out of view.

At a preprogrammed RADAR altitude or, in the event of no RAD ALT at the middle marker, the gains are changed in the computer so that GS (and LOC) sensitivity compensate for the closer proximity to LOC and GS antennas.

Go-Around Mode: When "go-around" is selected (by either the cyclic button or on the mode controller), a 4° FPA climb is commanded and a "go-around" mode annunicator segment will appear.

In all collective command operations (FPA, ALT, HOLD, GS, or Go-Around), a collective command pointer (Item 20, figure 2) above the zero FPA reference (Item 19, figure 2) indicates a need to increase collective. A command to lower collective is presented by the pointer being below the FPA zero reference line.

TWO-CUE FLIGHT DIRECTOR OPERATION

The Flight Director can be operated in two different two-cue configurations Configuration 'A' is identical to the previously described Three-cue systems with exception of the collective command functions. Configuration 'A' is established by placing the Two-cue/Three-cue switch located on Flight Director Control panel (figure 7) to the Two-cue position. When Two-cue operation is selected, the collective command is biased out of view. All other command functions and flight Director Modes are identical to Three-cue operation.

Configuration 'B' of Two-cue operation is limited to ILS approach operation only. In addition to biasing the collective command out of view as in Configuration 'A', the PITCH BAR FUNCTION switch, located on Mode C Control Panel (figure 9) must be placed in the GS (glide slope) position. The mode Annunciator should then be checked to assure that the p = A/S annunciator has changed to p= GS and thus confirming Two-cue configuration 'B' operation. An ILS approach can now be flown with glide slope displayed on the pitch command bar.

SECTION II TEST METHODOLOGY

A. CONDUCT OF THE FLIGHT

Each of the eight subject pilots flew a minimum of two familiarization flights. Maneuvers flown during these flights resembled, as closely as possible, those flown on data collection flights. The need to fly additional familiarization flights occurred only once and was required because of a long delay between completion of original familiarization flights and the start of data collection flights.

Each subject flew the profile described in figure 10 through 15 three times. One profile was flown without command information available(Gyro-Mode) The same profile was then repeated with Two-cue (roll and pitch) information being utilized and included in second ILS approach flown in Two-cue configuration "B". The third profile was flown with all three cues (pitch, roll and collective). The collective command commanded climbs and descents by means of a selected

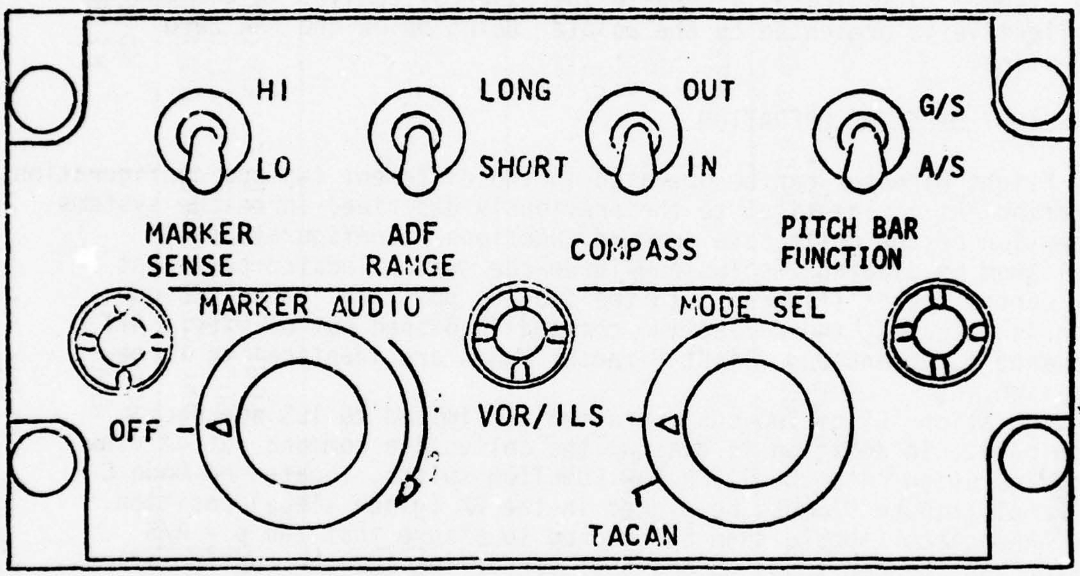


Figure 9.
MODE CONTROL PANEL, PEDESTAL CONSOLE

flightpath angle (FPA). This resulted in a slight change in the profile. For example, in the first two profiles, the pilot was tasked with a 55 knot, 1,000 foot per minute climb while the same maneuver on the Three-cue profile required the pilot to fly a 10° up flight-path angle (967 fpm).

The sequence in which each subject flew his three data flights was randomly varied to counterbalance effects of learning. Four subjects flew their profiles in the morning and four flew in the afternoon. Two subjects flew a Gyro-Two-Cue/Three-cue profile sequence while three subjects flew Three-cue/Two-cue/Gyro and the remaining subject flew a Two-cue/Gyro/Three-cue sequence. Each sortie was flown on separate days and averaged one hour duration.

Each subject was instructed to treat the data flights as if they were 'check rides'. They were asked to make every attempt to satisfy the performance criteria. This provided the subject pilots with a performance "GOAL" to strive for. A subjective performance criteria scale was also used to help structure the analysis of performance data. The performance criteria is contained in attachment 'G'.

All profiles were flown in Visual Meteorological Conditions (VMC) with subjects wearing an instrument hood. Additionally, subject pilots' chin window, side window and lower half of his windshield were covered. Project pilots insured that such factors as wind (maximum encountered 22 knots), turbulence, and other traffic did not adversely affect the subjects performance.

The project pilot acted as a co-pilot for the entire data flight and took control of the aircraft only at the completion of missed approach from both the precision and non-precision approaches.

In addition to the project and subject pilots, an IFC/RD human factors engineer and a psychologist from the School of Aerospace Medicine were on board for each data flight. Their duties were to monitor the on-board equipment and to help the project pilot clear for traffic.

Both subjective rating techniques and objective measurement procedures were employed during the in-flight investigation. Preflight and postflight questionnaires were given to each subject pilot to obtain firsthand impressions and opinions. The performance measurements included heading, altitude, vertical rate, and airspeed errors during upper air basic instrument maneuvers. During the terminal area navigation and instrument approaches, localizer deviation, and glide slope deviation replaced altitude and vertical rate errors as performance measures. Data was also collected on the functional commands to determine the ratio of correct/error response.

The control activity measurements included cyclic pitch, cyclic roll, collective lever, and rudder pedals.

B. OBJECTIVE DATA

A digital tape recorder was used to record the performance and activity parameters listed below.

Performance Parameters	Activity Parameters
Heading Datum Error	Cyclic Pitch
Airspeed Error	Cyclic Roll
Baro Altitude Error	Collective Lever Position
Vertical Rate Error	Rudder Pedals
Localizer Deviation	Bio/Med Data (ECG)
Glide Slope Deviation	
Collective Command	
Pitch Steering Command	
Roll Attitude	
Radar Altitude	
Event Marker	

Pitch Altitude
Radar Altitude
Event Marker
DME

C. SUBJECTIVE DATA

Pilot opinions and judgements were gathered using in-flight observations and pre and postflight questionnaires (atchs A - E). Subject pilot in-flight comments were recorded using an audio tape recorder. Comprehensive debriefing sessions conducted following each data collection flight to extract pertinent information concerning the acceptability/flyability of the flight director functicnal commands.

D. PSYCHOPHYSIOLOGICAL AND BIOCHEMICAL DATA

The data in this portion of the test plan was gathered by three different methods, electrocardiogram (ECG), urinalysis and survey.

HEARTRATE AND HEARTRATE VARIABILITY

During each flight, a continuous record of the subject's beat-by-beat heartrate was made onto one channel of the magnetic in-flight tape recorder. The signal from a three-lead ECG electrode harness, attached to the subject's chest, was amplified through a Holter Monitor recorder to a cardiotachometer. The cardiotach measured the interval between successive beats and converted this value to heartrate in beats per minute (BPM). In addition, the analog tape recording of the entire ECG trace on the Holter Monitor provided a backup to check the quality of cardiotach values. The digital heartrate data was collated by flight elements and segments after treatment by a computer program that smoothed data values by removing radio magnetic interference spikes and other transient signal spikes. This editing process is continuing because some of the smoothed values appear lower than normal cardiac responses for similar situations, and may require limiting for signal drop out.

Analysis of heartrate and heartrate variability will proceed when the editing of the data can be accomplished, but will not be available at the time of this report. A mean rate for each segment will be established by computing the average of all cardiotach values recorded in a 30-second epoch (5 samples/sec, 150/epoch) and the average rate for all epochs in the segment. After smoothing, heartrate variability related to sinus arrythmia will be determined by analizing the beat-by-beat changes in cardiotach output. A heartrate variability index will be established for each 30 second epoch. Each successive cardiotach value is subtracted from the preceding value and the absolute values of the subtrahends are summed through each epoch. The number of reversals in direction of change is found by multiplying successive subtrends and counting the negative products as reversals. The ratio of variability to reversals is the index score for each epoch.

URINALYSIS

Subjects were required to force void all urine from their bladder approximately 1 1/2 hours before the flight. This procedure eliminates the effect of some intervening variables and assures adequate volume for subsequent urine samples. A urine sample was collected within 30 minutes after each flight and at approximately

the same time on three baseline days when the subject did not fly during the corresponding time period. Each urine sample was collected into dilute HCl acid and immediately frozen for later biochemical analysis at Brooks AFB.

The urinary determinations routinely used for the USAFSAM stress battery are: (1) Norepinepherne (NE), an index of sympathetic nervous system activity; (2) Epinepherine (E), adrenomedulary activity; (4) Urea, protein catabolism; and (5) Sodium (NA) and (6) Potassium (K), mineral metabolism. In addition, the ratio of Na to K is calculated as an index of metabolic balance (homeostasis). Increases in some or all of these variables have been correlated with environmental stresses, physical and mental work and fatigue.

Urinary Creatinine, a close correlate of lean body mass is used as an adjusting factor for the other variables. Each urinary measure is stated in a ratio to 100 mg of Creatinine, which corrects for variations in the timing of sample collection and subject variables such as body size and age.

SURVEYS AND QUESTIONNAIRES

The subjects in this study were expected to be normally rested and healthy, but in order to assess the possibility of intervening variables such as night work or illness, subjects were asked to complete a SAM Form 154, Sleep Survey (Atch F) before each flight and base line sampling period. The form requires them to list all sleep during the past 30 to 48 hours and asks them to comment on the value of their rest.

SAM Form 136 Subjective Fatigue Checkcards (Atch F) were completed by each subject at the same time as the sleep survey and at the end of each flight or time of urine sampling on baseline days. The subjective fatigure checkcard yields a score from 0-20 with lower scores indicating feelings of greater fatigue. Because of runway traffic, ILS attempts varied greatly for different flights at the beginning of the test program so the post flight fatigue as sessment was changed to include one card after the missed approach for TACAN and one after the final ILS approach. The two cards were averaged to give one score.

E. DATA ANALYSIS

The following performance criteria was established for reduction and analysis of the objective data.

Performance Parameter	Highly Qualified*	Qualified*	Unqualified*
Vertical Rate Error	±100 fpm	±101 to +200 fpm	±200 fpm
Bank Angle Error	±3°	±4° to +5°	±5°
Altitude Error	±50'	±51' to ±100'	±100'
Airspeed Error	±5 kts	±6 kts to ± 10 kts	± 10 Kts
CDI Error	±.25 dot	±.26 to 1.00 dot	±1.00 dot
LOC Error	±.25 dot	±.26 to 1.00 dot	±1.00 dot
GS Error	±.25 dot	±.26 to 1.00 dot	±1.00 dot

Command Zeroed*	Command Deviated*
Pitch/Roll CMD	±2 Barwidths
Collective CMD	±1° FPA

*In order to apply the performance criteria, the above parameters had to be maintained for 5 seconds or more to be considered a steady state condition (as opposed to a momentary deviation). This time restriction limited the transitory effects of turbulence, momentary distractions, and short-time real world problems encountered in the cockpit. The judgement of several highy experienced instrument instructors and flight examiners was that a deviation of more than 15 seconds would identify such things as an improper cross-check, poor pilot technique, or possible display deficiency of real world significance. Since highly experienced helicopter instrument pilots were used as test subjects, the time factor was reduced from 15 seconds to 5 seconds to increase differential criticality between the three configuration modes.

In addition to the performance parameter data analysis, a program was developed to analyze the four helicopter control parameters, cyclic roll, cyclic pitch, tail rotor, and collective. Steady state bandwidths were established for each control parameter based upon the sensitivity of each channel (normally one to two percent of full travel of the control).To meet steady state requirements, the control had to be held within the predetermined bandwidth for one second or more. A steady state control condition held less than one second was termed "steady state transient" conditicn and was compiled as such.

A control movement was sensed when the control parameter exceeded the steady state criteria bandwidth in either direction. The number of control movements were counted and the total number for a given segment were divided by the segment duration. This provided a frequency index for the respective controls, and was termed Control Frequency Index (CFI). The following chart shows relative CFI Values.

CFI .01 = 1 Control movement every 2 minutes
CFI .02 = 1 Control movement every minute
CFI .06 = 1 Control movement every 25 seconds
CFI .13 = 1 Control movement every 8 seconds
CFI .25 = 1 Control movement every 4 seconds
CFI .50 = 1 Control movement every 2 seconds
CFI 1.00 = 1 Control movement every second
CFI 1.50 = 1.5 Control movements every second
CFI 2.00 = 2 Control movements every second

The CFI's were an important factor in quantifying the quality of performance with the degree of activity necessary to attain the performance. This provided a performance activity ratio (PAR) for each segment. The PAR's were derived by taking the percent of time the performance was not Hi Qual and multiplying this value by CFI of the associated control. The resultant factor was then subtracted from the percent of time the performance was Hi Qual. This produced a single value for comparative evaluation which included both performance and activity terms.

EXAMPLES

% H/Qual - (% $\overline{\text{H/Qual}}$ X CFI = PAR Index)
75% - (25% X .25) = 68.75
50% X .50) - 25.00

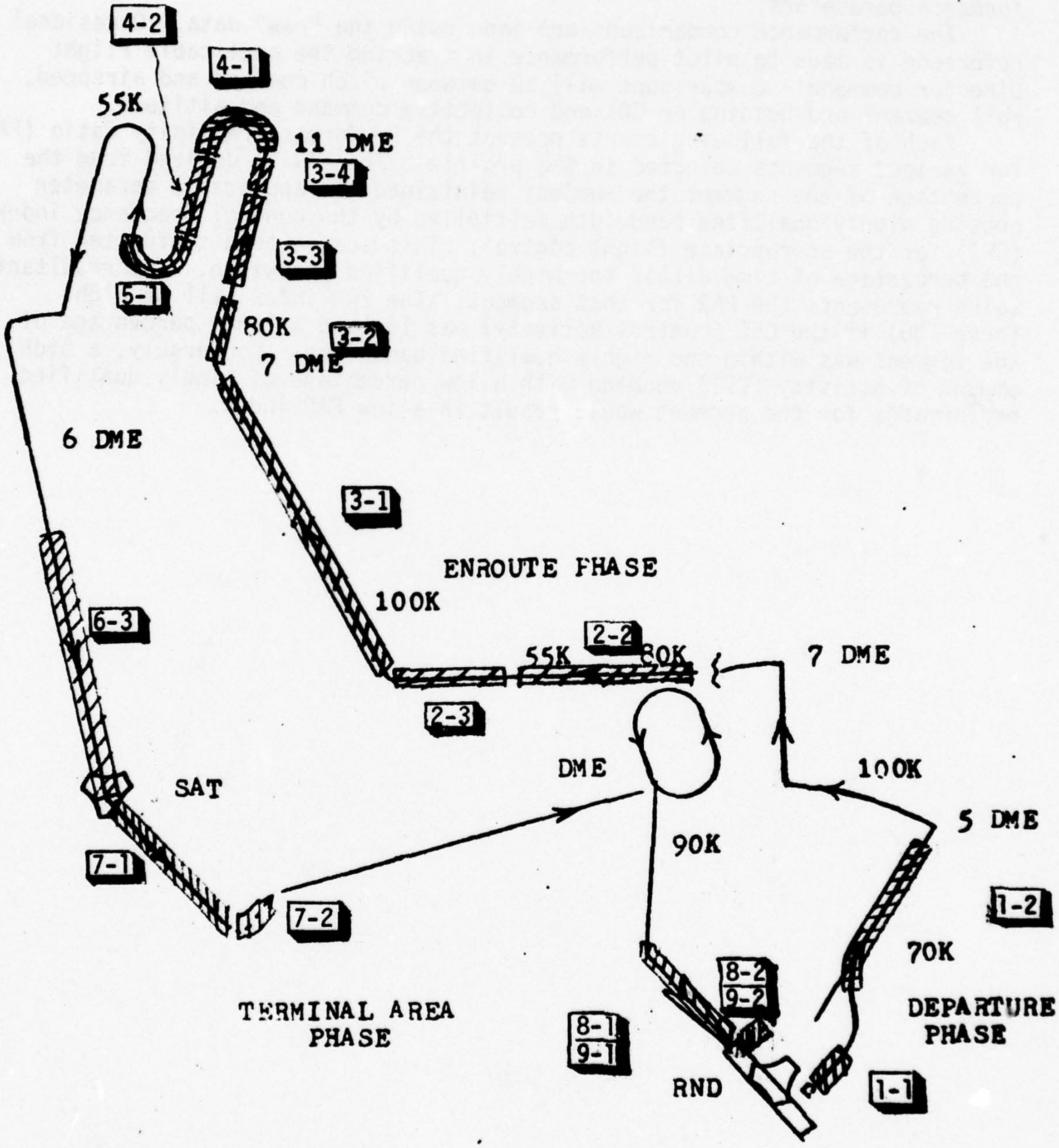
The applicable performance parameters for each segment are addressed by pilot task. For example, in the gyromode the pilot is tasked with keeping air-speed within the highly qualified bandwidth using the cyclic pitch control. For the same segment in either the Two or Three-cue modes, the pilot is tasked

with keeping the pitch bar within the highly qualified bandwidths by using cyclic pitch. The pitch bar in turn is coupled to maintain airspeed. A similar situation exists for the roll and collective commands in that the pilot task is to track the commands and keep them within the HIQUAL bandwidths. These commands, in turn, are coupled to maintain respective performance parameters.

The performance comparisons are made using the "raw" data. Occasional reference is made to pilot performance in tracking the applicable Flight Director command. Comparisons will be between pitch command and airspeed, roll command and heading or CDI and collective command and altitude.

Each of the following charts present the Performance/Acticity Ratio (PAR) for various segments selected in the profile. The PAR is derived from the percentage of the segment the subject maintained the applicable parameter outside highly qualified bandwidth multiplied by the control frequency index (CFI) for the appropriate flight control. This sum is then subtracted from the percentage of time within the highly qualified bandwidth. The resultant value represents the PAR for that segment. The PAR index will be high (near 100) if the CFI (control activity) was low and a large percentage of the segment was within the highly qualified bandwidth. Conversely, a high amount of activity (CFI) coupled with a low percentage of highly qualified performance for the segment would result in a low PAR index.

FLIGHT DIRECTOR DATA FLIGHT PROFILE



SHADED AREAS REPRESENT SEGEMENTS ANALYZED

Figure 10

SECTION III

FINDINGS

A. OBJECTIVE DATA FINDINGS

Element 1, Segment 1 Description:

Pilot was tasked with an instrument takeoff. Manuever was started from a stabilized position on the ground. Lift off power was set at 50-75 pounds of fuel flow above hoverpower. The pilot task included maintaining heading and establishing a five degree nose down pitch attitude when the pilot was assured he was clear of ground. The aircraft was then accelerated to 70 Kts and a climb established to 1300' indicated altitude. The segment ended when the aircraft reached 70 knots or 1000 feet, whichever occurred first. In the Gyro mode the pilot used heading and airspeed markers ("Bugs") set to the desired heading and airspeed. When flying with flight director engaged the roll command was in view for maintaining heading. Depending upon which configuration was being flown, (Two-cue or Three-Cue) both pitch (airspeed) and collective commands came into view once the aircraft was above 30 Kts.

Element 1, Segment 1 Findings (See Table 1):

The instrument takeoff heading performance comparison showed that improved heading control was achieved by use of the flight director (F/D) roll command. A slight reduction in cyclic roll inputs was also noted when the pilots used the roll command. However, subject four was the only pilot able to achieve better performance without the F/D System. Airspeed and altitude performance varied during instrument takeoff due to the individual pilot techniques.

TABLE 1

Heading* Element 1 Segment 1 Average Duration 38

SUBJECT PILOT		1	2	3	4	5	6	7	8	M	SD
	%HIQUAL	61.2	82.0	54.9	91.3	ND	61.7	43.2	79.3	67.7	7.0
GYRO	CFI	.22	.16	.03	.54	ND	.07	.03	.67	.25	.26
MODE	PAR	52.7	79.1	53.6	86.6	ND	59.0	41.5	65.4	62.6	15.8
	%HIQUAL	89.8	44.5	73.3	88.5	ND	59.8	62.0	91.4	69.7	17.7
2-CUE	CFI	.17	.55	.03	.14	ND	.17	.18	.25	.21	.16
MODE	PAR	88.1	14.0	71.5	86.9	ND	53.0	55.2	89.3	65.4	27.3
	%HIQUAL	59.0	90.3	66.7	74.3	76.1	74.1	64.5	79.3	72.1	10.1
3-CUE	CFI	.53	.09	.07	.07	.28	.05	.21	.07	.17	.17
MODE	PAR	37.3	89.4	66.8	72.5	69.4	72.8	57.1	77.9	67.9	15.4

* 140°

% HIQUAL F = 0.29 DOF 2 / 19

CFI F = 0.26 DOF 2 / 19

PAR F = 0.13 DOF 2 / 19

Element 1, Segment 2 Description:

Data analyzed for Element 1, segment 2 began when aircraft was within 10° of 030 Radial and stopped when aircraft arrived at 4.0 DME. Subject was tasked with maintaining 1300' PA and 100 Kts. His navigation task was to intercept the 030 Radial outbound. When flight director (F/D) commands were in view (two and three-cue profiles) his task was to keep commands centered at all times. When profiles were flown in the Gyro mode, the subjects were asked to apply their normal instrument techniques and cross-check with the only exception being the requirement to use 15° angle of bank for all turns. Normal instrument techniques would usually call for standard rate turn angle of banks. These instructions applied to all segments flown during this study.

Element 1, Segment 2 Findings (See Tables 2, 3, 4):

Airspeed performance showed slight improvement when flown with the pitch command in view. This improved performance was achieved using slightly more cyclic pitch control inputs. The highest activity (CFI's) were usually found in conjunction with the poorest performance (i.e., subject five).

The navigation task was greatly improved while flying in the two and three-cue modes. As was the case with airspeed performance, improved heading performance required slightly higher pilot control activity. Only subjects five and six were able to achieve better performance while flying in gyro mode.

Altitude performance was slightly better in the gyro mode than in the F/D mode. The addition of the third cue resulted in a reduction in *collective lever activity*. The correlation between high activity and poor performance, as evidenced in heading and airspeed performance parameters, was not found in the case of altitude performance. This might suggest that poor performance in the vertical axis resulted from inattention on the part of the pilot rather than increased activity.

TABLE 2

Airspeed*

Element 1 Segment 2 Average Duration 111

SUBJECT	PILOT	1	2	3	4	5	6	7	8	M	SD
	%HIQUAL	97.2	24.2	34.7	0.0	20.0	60.3	0.0	83.3	40.0	36.7
GYRO	CFI	.13	.35	.16	.39	.25	.29	.48	.16	.28	.12
MODE	PAR	96.8	51.6	24.3	-.39	0.0	48.8	-48	80.6	26.9	52.8
	H/R	106.6	114.4	ND	99.6	100.5	115.5	91.9	90.5	102.7	10.0
	%HIQUAL	86.4	95.2	0.0	45.8	0.0	78.0	88.0	0.0	49.2	43.3
2-CUE	CFI	.11	.38	.41	.24	.71	.36	.31	.26	.35	.17
MODE	PAR	84.9	93.4	-.41	32.8	-71	70.1	84.3	-26	28.4	65.4
	H/R	83.4	99.6	93.9	100.3	110.2	129.4	88.3	91.9	100.2	13.9
	%HIQUAL	92.5	52.5	47.8	29.5	0.0	85.9	94.9	0.0	57.6	35.7
3-CUE	CFI	.06	.25	.25	.28	.59	.20	.34	.43	.30	.16
MODE	PAR	92.1	40.6	34.8	9.8	-59	87.1	93.2	-43	32.0	59.6
	H/R	83.3	106.9	94.7	98.9	98.6	118.1	94.9	104.8	99.3	8.9

* 100 Knots

% HIQUAL F = 0.93 DOF 2 / 21

CFI F = 0.44 DOF 2 / 21

PAR F = 0.01 DOF 2 / 21

H/R F = 0.19 DOF 2 / 20

TABLE 3

* CDI

Element 1 Segment 2 Average Duration 111

SUBJECT PILOT		1	2	3	4	5	6	7	8	M	SD
	%HIQUAL	23.6	50.4	45.0	4.7	43.4	49.9	24.7	20.9	32.8	16.7
GYRO	CFI	.19	.39	.38	.59	.46	.37	.57	.12	.38	.16
MODE	PAR	9.1	31.1	24.1	-51.5	17.4	31.4	-18.2	11.4	6.9	28.4
	%HIQUAL	40.7	44.5	48.5	59.0	19.7	56.4	53.5	44.5	45.9	12.3
2-CUE	CFI	.32	.80	.48	.53	.62	.25	.48	.23	.46	.19
MODE	PAR	21.7	.10	23.8	37.3	-30.1	45.5	31.2	31.7	18.9	23.9
	%HIQUAL	44.1	55.3	58.6	49.0	30.9	17.8	45.0	44.1	43.2	13.2
3-CUE	CFI	.21	.49	.35	.52	.30	.49	.61	.32	.41	.14
MODE	PAR	32.4	33.4	44.1	22.5	10.2	-22.5	11.5	26.2	19.7	20.5

* R-030

% HIQUAL F = 1.87 DOF 2 / 21

CFI F = 0.48 DOF 2 / 21

PAR F = 0.75 DOF 2 / 21

TABLE 4

* Altitude

Element 1 Segment 2 Average Duration 111

SUBJECT PILOT		1	2	3	4	5	6	7	8	M	SD
	%HIQUAL	52.5	72.4	62.6	97.5	100	59.1	100	76.4	77.6	19.4
GYRO	CFI	.02	.07	.01	.01	.06	.01	.05	.08	.04	.03
MODE	PAR	51.6	70.5	62.1	97.5	99.9	58.7	100	74.5	76.9	19.7
	%HIQUAL	63.1	70.9	46.8	17.4	75.9	72.0	100	99.8	68.2	27.1
2-CUE	CFI	.01	.01	.01	.02	.06	.07	.02	.02	.03	.02
MODE	PAR	62.7	70.6	46.3	15.8	74.5	70.0	99.9	99.8	67.5	27.5
	%HIQUAL	57.1	66.6	84.8	63.9	100	48.8	87.3	89.3	74.7	13.0
3-CUE	CFI	.01	.01	.01	.01	.04	.04	.05	.01	.02	.02
MODE	PAR	93.5	70.8	84.7	70.7	100	46.8	86.7	89.2	80.3	16.9

* 1300 feet

% HIQUAL F = 0.38 DOF 2 / 21

CFI F = 0.95 DOF 2 / 21

PAR F = 0.74 DOF 2 / 21

Element 2, Segment 1 Description:

Element 2 - Segment 2 tasked the pilot with maintaining 80 Kts, 1500 feet and heading 270°.

Element 2, Segment 2 Findings (See Tables 5, 6, 7):

The best airspeed performance/activity ratio (PAR) was recorded while flying without the pitch command in view. Three-cue performance was generally better than Two-cue performance. The analysis of variance (ANOVA) indicated significant variance between gyro mode and two/three cue profiles. This variance was attributed to the addition of the pitch command.

The highest heading PAR (mean) was recorded while flying in the Gyro mode. As with airspeed, three-cue heading performance (PAR) was higher than two-cue. With subject five's data removed, a significant change in the the PAR mean indices resulted. The three-cue mean index would be increased to 89.9 with a standard deviation of 14.6. Whereas the two-cue mean index would decrease well below 94.0. The impact of one deviant subject in a sample of eight can be highly critical.

Altitude performance was slightly better without the collective command but degraded slightly when flown with pitch and roll commands in view (two-cue). As in the case of heading performance, the deletion of subject five's data would change the mean considerably. The three-cue performance ratio would then be the highest (Mean = 77.9, Sd - 13.2) and two-cue would be much lower.

TABLE 5

*Airspeed Element 2 Segment 2 Average Duration 128

SUBJECT	PILOT	1	2	3	4	5	6	7	8	M	SD
	%HIQUAL	81.0	71.0	82.4	77.9	ND	61.8	72.0	ND	74.4	7.7
GYRO	CFI	.01	.30	.17	.18	ND	.24	.12	ND	.17	.10
MODE	PAR	80.1	62.3	79.4	73.9	ND	52.6	68.8	ND	69.5	10.7
	H/R	91.2	116.2	96.8	106.8	ND	119.9	87.8	ND	103.1	13.3
	%HIQUAL	ND	60.2	41.8	ND	65.4	56.4	49.7	55.1	54.8	8.2
2-CUE	CFI	ND	.20	.19	ND	.10	.14	.21	.07	.15	.06
MODE	PAR	ND	52.2	30.1	ND	61.9	50.3	39.1	52.0	47.6	11.2
	H/R	ND	100.7	96.3	ND	109.3	125.9	82.8	92.2	101.2	15.0
	%HIQUAL	83.8	66.0	64.7	57.5	63.9	55.2	33.8	52.3	59.7	14.2
3-CUE	CFI	.12	.41	.13	.17	.18	.12	.33	.12	.20	.11
MODE	PAR	60.7	48.0	60.1	50.3	57.4	46.2	12.0	46.6	47.7	15.6
	H/R	85.1	110.9	96.0	99.4	100.4	111.4	85.9	103.7	98.9	10.4

* 80 Knots

% HIQUAL F = 8.45 DOF 2 / 16**

CFI F = 0.41 DOF 2 / 17

PAR F = 5.89 DOF 2 / 17 ***

H/R F = 0.20 DOF 2 / 17

** F= .995(2/16) = 7.51

*** F= .975(2/17) = 4.62

TABLE 6

* Heading Element 2 Segment 2 Average Duration 128

SUBJECT PILOT		1	2	3	4	5	6	7	8	M	SD
	%HIQUAL	100	100	86.7	95.5	ND	76.0	91.7	ND	91.7	9.2
GYRO	CFI	.35	.48	.16	.60	ND	.38	.60	ND	.43	.17
MODE	PAR	99.7	99.5	84.6	92.8	ND	66.9	86.7	ND	88.4	12.3
	%HIQUAL	ND	97.8	100	ND	48.5	84.6	90.6	98.9	86.7	19.6
2-CUE	CFI	ND	.64	.35	ND	.66	.38	.57	.29	.48	.16
MODE	PAR	ND	96.4	99.7	ND	14.5	78.8	85.2	98.6	78.9	32.6
	%HIQUAL	100	98.3	91.5	99.0	63.7	81.1	60.5	98.9	86.6	16.3
3-CUE	CFI	.17	.43	.27	.35	.45	.33	.11	.23	.29	.12
MODE	PAR	99.8	97.6	89.2	98.7	47.4	74.9	56.1	98.7	82.8	21.0

* 270°

% HIQUAL F = 0.29 DOF 2 / 17

CFI F = 3.09 DOF 2 / 17

PAR F = 0.25 DOF 2 / 17

TABLE 7

*Altitude Element 2 Segment 2 Average Duration 128

SUBJECT PILOT		1	2	3	4	5	6	7	8	M	SD
	%HIQUAL	86.4	78.7	58.1	58.6	ND	79.5	68.0	ND	71.6	11.8
GYRO	CFI	.01	.11	.01	.03	ND	.01	.02	ND	.03	.04
MODE	PAR	86.3	76.4	57.7	57.4	ND	79.3	67.4	ND	70.8	11.9
	%HIQUAL	ND	70.0	40.6	ND	86.9	0.0	100	80.8	63.1	36.8
2-CUE	CFI	ND	.01	.01	ND	.03	.01	.03	.01	.02	.01
MODE	PAR	ND	69.7	40.0	ND	89.5	-1	100	80.6	63.1	37.6
	%HIQUAL	86.9	66.0	70.8	83.8	8.1	57.1	90.8	89.6	69.1	27.5
3-CUE	CFI	.04	.06	.03	.02	.05	.04	.03	.02	.04	.01
MODE	PAR	86.4	63.4	69.9	83.5	3.5	55.4	90.5	89.9	67.8	29.0

* 1500 feet

% HIQUAL F = 0.16 DOF 2 / 17

CFI F = 1.22 DOF 2 / 17

PAR F = 0.11 DOF 2 / 17

Element 2, Segment 3 Description:

During element 2 Segment 3, the subjects were tasked with maintaining heading and altitude (see 2-1) while decelerating to 55 Kts. Segment began when subject first attained High Qual bandwidth for each performance parameter. Segment ended at five DME.

Element 2, Segment 3 Findings: (See Tables 8, 9, 10):

Airspeed performance without the pitch command is slightly better than with bar in view. The pilot activity was almost twice as high in gyro mode flights than in either two or three-cue flights. Once again, removal of subject five would significantly change the airspeed PAR's.

Heading performance was improved while flying in the three-cue mode. This improved performance was achieved with a reduction of pilot activity in cyclic roll inputs.

Removal of subject five's data would spread the data even further. Attitude mean PAR was highest in the gyro mode. The 10% difference in gyro and three-cue attitude PAR's is a result of the subjects not being "highly qualified" while tracking the collective command 35% of the time.

TABLE 8

* Airspeed

Element 2 Segment 3 Average Duration 168

SUBJECT PILOT		1	2	3	4	5	6	7	8	M	SD
GYRO MODE	%HIQUAL	76.1	48.0	88.3	72.9	ND	68.6	90.3	ND	74.0	15.4
	CFI	.02	.18	.03	.14	ND	.05	.05	ND	.08	.07
	PAR	75.6	38.6	88.0	69.1	ND	67.0	89.8	ND	71.4	18.6
	H/R	95.7	117.2	96.6	107.7	ND	119.1	86.4	ND	103.8	8.2
2-CUE MODE	%HIQUAL	ND	81.3	75.4	ND	58.8	62.7	71.4	68.1	69.6	8.2
	CFI	ND	.05	.01	ND	.04	.03	.04	.01	.03	.02
	PAR	ND	80.4	75.2	ND	57.2	61.6	70.3	67.8	68.8	8.6
	H/R	ND	101.8	94.0	ND	109.7	130.1	81.8	91.1	101.4	16.9
3-CUE MODE	%HIQUAL	93.2	75.9	73.5	76.2	63.3	60.4	65.5	49.7	69.8	13.1
	CFI	.03	.01	.06	.05	.02	.02	.07	.05	.04	.02
	PAR	93.0	75.7	71.9	75.0	62.6	59.6	63.1	47.2	68.5	13.6
	H/R	86.4	112.8	97.3	98.8	99.3	110.2	85.1	133.4	102.9	15.7

* 55 Knots

% HIQUAL F = 0.25 DOF 2 / 17

CFI F = 2.65 DOF 2 / 17

PAR F = 0.08 DOF 2 / 17

H/R F = 0.04 DOF 2 / 17

TABLE 9

* Heading Element 2 Segment 3 Average Duration 168

SUBJECT PILOT		1	2	3	4	5	6	7	8	M	SD
	%HIQUAL	91.5	96.0	64.2	67.6	ND	70.6	92.9	ND	80.5	14.5
GYRO	CFI	.28	.17	.25	.70	ND	.47	.30	ND	.36	.19
MODE	PAR	89.1	95.3	55.3	44.9	ND	56.8	90.8	ND	72.0	22.1
	%HIQUAL	ND	72.5	87.5	ND	53.1	77.6	80.4	95.9	77.8	14.6
2-CUE	CFI	ND	.47	.29	ND	.66	.22	.52	.19	.39	.19
MODE	PAR	ND	59.6	83.9	ND	22.2	72.7	70.2	95.1	67.3	25.2
	%HIQUAL	87.3	92.5	96.9	91.3	56.6	88.5	64.3	98.0	84.4	15.4
3-CUE	CFI	.21	.15	.07	.22	.48	.33	.25	.17	.24	.12
MODE	PAR	84.6	91.4	96.7	89.4	35.8	84.7	55.4	97.9	79.5	22.1

* 270°

% HIQUAL F = 0.07 DOF 2 / 20

CFI F = 0.13 DOF 2 / 20

PAR F = 0.10 DOF 2 / 20

Table 10

* Altitude Element 2 Segment 3 Average Duration 168

SUBJECT PILOT		1	2	3	4	5	6	7	8	M	SD
	%HIQUAL	47.7	79.4	73.0	83.3	ND	81.7	73.9	ND	73.2	13.1
GYRO	CFI	.03	.05	.01	.01	ND	.02	.03	ND	.03	.02
MODE	PAR	46.1	78.4	72.7	83.1	ND	81.3	73.1	ND	72.5	13.6
	%HIQUAL	ND	60.4	78.9	ND	96.0	0.0	100	100	72.6	38.8
2-CUE	CFI	ND	.01	.01	ND	.01	.05	.01	.01	.02	.02
MODE	PAR	ND	60.0	78.7	ND	96.0	-5	100	100	71.6	40.7
	%HIQUAL	51.7	86.6	41.0	67.0	63.2	15.9	100	84.1	63.7	27.3
3-CUE	CFI	.02	.08	.03	.04	.04	.01	.10	.03	.04	.03
MODE	PAR	50.7	85.5	39.2	65.7	61.7	15.1	99.9	83.6	62.7	27.6

* 1500 Feet

% HIQUAL F = 0.25 DOF 2 / 17

CFI F = 2.68 DOF 2 / 17

PAR F = 0.25 DOF 2 / 17

Element 3, Segment 1 Description:

Element 3, Segment 1 began at five DME and ended when aircraft was within 10° of the R-015. Subject was instructed to turn to a Heading of 330° while maintaining 55 Knots and 1500'. Turn was accomplished with a 15° angle of bank.

Element 3, Segment 1 findings (See Tables 11, 12, 13):

Airspeed mean PAR's show a slight improvement in the three-cue profile. The removal of subject five's data would again greatly alter the data means. The greatest influence would be a large reduction in the CFI mean for three-cue cyclic pitch activity.

The lowest pilot activity and highest heading performance was achieved in the two-cue mode. Subject five's extremely low performance influenced the high standard deviations in the gyro three-cue mode performance means.

Altitude control was greatly improved by the addition of the third cue. This is especially noteworthy since the CFI for gyro and three-cue are the same (.03). Subject five had a similar effect on the altitude data as he had on airspeed and heading data.

Table 11

*Airspeed — Element 3 Segment 1 Average Duration 148

SUBJECT PILOT		1	2	3	4	5	6	7	8	M	SD
	%HIQUAL	33.4	53.4	52.9	49.1	0.0	45.4	50.6	76.0	45.1	21.7
GYRO MODE	CFI	.07	.09	.06	.11	.35	.25	.12	.07	.14	.10
	PAR	28.7	49.2	50.1	43.5	-35	31.7	44.7	74.3	35.9	31.8
	H/R	93.4	116.1	96.5	101.0	ND	117.5	85.1	91.9	101.1	12.6
	%HIQUAL	39.4	51.6	29.8	64.1	34.3	ND	0.0	69.3	41.2	23.5
2-CUE MODE	CFI	.07	.12	.01	.20	.10	ND	.49	.25	.18	.16
	PAR	35.2	45.8	29.1	56.9	27.7	ND	-49	61.6	29.6	37.1
	H/R	92.2	103.2	96.5	104.0	110.5	ND	88.3	96.7	98.8	7.6
	%HIQUAL	40.8	59.8	39.6	34.8	0.0	35.2	84.7	66.2	45.1	25.4
3-CUE MODE	CFI	.03	.10	.10	.12	.32	.09	.42	.05	.15	.14
	PAR	39.0	55.8	33.6	27.0	-32	29.4	78.3	64.5	37.0	33.3
	H/R	86.7	110.6	95.3	96.8	98.5	110.9	90.5	104.8	99.3	8.9

* 100 Knots

% HIQUAL F = 0.07 DOF 2 / 20

CFI F = 0.13 DOF 2 / 20

PAR F = 0.10 DOF 2 / 20

H/R F = 0.4 DOF 2 / 19

Table 12

* Heading Element 3 Segment 1 Average Duration 148

SUBJECT PILOT		1	2	3	4	5	6	7	8	M	SD
	%HIQUAL	94.2	87.2	69.2	75.7	7.1	31.9	54.6	97.9	64.7	31.9
GYRO	CFI	.42	.34	.41	.35	.70	.18	.47	.35	.40	.15
MODE	PAR	91.8	82.9	56.6	67.2	-57.9	19.6	33.3	97.2	48.8	51.0
	%HIQUAL	99.4	87.4	95.8	91.7	86.6	ND	100	93.8	93.5	5.3
2-CUE	CFI	.35	.03	.03	.24	.17	ND	.55	.33	.24	.19
MODE	PAR	99.2	87.0	95.6	89.7	84.3	ND	99.5	91.8	92.4	5.9
	%HIQUAL	100	98.2	83.2	99.6	44.4	90.1	56.3	90.4	82.8	21.0
3-CUE	CFI	.22	.37	.04	.13	.73	.23	.41	.34	.31	.21
MODE	PAR	99.8	97.5	82.5	99.5	3.8	87.8	38.4	87.1	74.6	34.8

* 330°

% HIQUAL F = 3.04 DOF 2 / 20

CFI F = 1.44 DOF 2 / 20

PAR F = 2.69 DOF 2 / 20

Table 13

*Altitude Element 3 Segment 1 Average Duration 148

SUBJECT PILOT		1	2	3	4	5	6	7	8	M	SD
	%HIQUAL	73.2	100	79.7	58.3	0.0	0.0	25.2	100	54.6	41.3
GYRO	CFI	.01	.02	.01	.18	.01	.01	.02	.01	.03	.06
MODE	PAR	72.9	99.9	79.5	50.8	-1	-1	23.7	99.9	53.1	41.7
	%HIQUAL	63.7	90.0	0.0	66.7	59.1	ND	0.0	65.4	49.3	35.0
2-CUE	CFI	.01	.01	.01	.02	.01	ND	.04	.01	.02	.01
MODE	PAR	63.3	89.9	-1	66.0	58.7	ND	-4	65.1	48.3	36.1
	%HIQUAL	87.3	92.5	96.9	91.3	56.6	88.5	64.3	98.0	84.4	15.4
3-CUE	CFI	.01	.02	.02	.01	.06	.01	.08	.02	.03	.02
MODE	PAR	87.2	92.4	96.8	91.2	54.0	88.4	62.2	97.9	83.8	16.4

* 1800 Feet

% HIQUAL F = 2.65 DOF 2 / 20

CFI F = 0.43 DOF 2 / 20

PAR F = 2.62 DOF 2 / 20

Element 3, Segment 2, Description:

Analysis of element 3, Segment 2 began when aircraft was within 1/4° of 015R and within highly qualified bandwidths for 100 kts and 1800' pressure altitude. Segment analysis stopped at 8 DME.

Element 3, Segment 2 findings (See Tables 14, 15, 16):

Airspeed performance was better without the F/D on. Only subject eight was able to do better his gyro mode PAR while flying two and three-cue during this segment.

Subjects were able to track the selected radial better with the F/D roll command in view.

Altitude control was better without the third cue in view. Note the effect of subject eights high activity and low performance on the three-cue means. Subject eight did not maintain the collective command centered for 22% of the segment.

Table 14

* Airspeed — Element 3 Segment 2 Average Duration 136

SUBJECT PILOT		1	2	3	4	5	6	7	8	M	SD
	%HIQUAL	74.1	48.7	36.8	62.3	50.8	82.2	75.3	35.8	58.3	17.9
GYRO	CFI	.39	.41	.38	.53	.03	.65	.61	.39	.42	.19
MODE	PAR	64.0	27.7	12.8	42.3	49.3	70.6	60.2	10.8	42.2	23.0
	H/R	92.9	113.0	93.8	105.8	102.0	104.9	90.6	89.0	99.0	8.6
	%HIQUAL	65.7	29.2	34.1	26.9	53.2	27.4	51.5	40.5	41.1	14.3
2-CUE	CFI	.06	.83	.09	.15	.88	.19	.25	.25	.34	.33
MODE	PAR	63.6	-29.6	28.2	15.9	12.0	13.6	-12.1	25.6	25.1	17.2
	H/R	71.9	101.1	91.5	102.3	104.8	133.4	82.7	91.3	97.4	18.2
	%HIQUAL	56.8	42.7	36.3	24.2	29.2	32.6	30.3	45.9	37.3	10.6
3-CUE	CFI	.12	.57	.39	.33	.09	.38	.52	.31	.34	17.0
MODE	PAR	51.6	10.0	11.5	-.09	22.9	7.0	-5.9	29.1	17.3	16.8
	H/R	88.2	111.8	92.6	97.3	102.7	110.1	86.9	99.8	98.7	9.3

* 100 Knots

% HIQUAL F = 4.70 DOF 2 / 21**

CFI F = 0.34 DOF 2 / 21

PAR F = 3.57 DOF 2 / 21***

H/R F = 0.04 DOF 2 / 21

***F .95 (2/24 =3.47

**F.975 (2/21) = 4.42

Table 15

* CDI

Element 3 Segment 2 Average Duration 136

SUBJECT PILOT		1	2	3	4	5	6	7	8	M	SD
	%HIQUAL	32.3	41.6	45.8	37.3	18.8	46.9	35.1	52.8	38.8	10.5
GYRO	CFI	.43	.55	.22	.46	.53	.48	.41	.34	.43	.11
MODE	PAR	3.2	9.5	33.9	8.5	-24.2	21.4	8.5	36.8	18.3	12.7
	%HIQUAL	47.6	55.0	34.4	53.6	32.5	52.4	45.1	42.3	45.4	8.5
2-CUE	CFI	.42	.70	.41	.46	.64	.20	.63	.16	.45	.20
MODE	PAR	25.6	23.5	7.5	32.3	-10.7	42.9	10.5	33.1	23.3	12.8
	%HIQUAL	43.9	51.2	62.0	50.9	40.2	45.7	36.5	61.7	49.1	9.3
3-CUE	CFI	.20	.63	.35	.43	.52	.30	.59	.25	.41	.16
MODE	PAR	32.7	20.5	48.7	29.8	9.1	29.4	-1.0	52.1	27.9	17.6

* R-015

% HIQUAL F = 0.31 DOF 2 / 21

CFI F = 0.15 DOF 2 / 21

PAR F = 1.45 DOF 2 / 21

Table 16

* Altitude

Element 3 Segment 2 Average Duration 136

SUBJECT PILOT		1	2	3	4	5	6	7	8	M	SD
	%HIQUAL	58.4	84.9	70.0	70.3	100	75.7	54.3	84.1	74.7	14.9
GYRO	CFI	.01	.01	.03	.04	.01	.03	.06	.08	.03	.03
MODE	PAR	58.0	84.8	69.1	69.1	100	75.0	51.6	82.8	73.8	15.5
	%HIQUAL	75.9	97.7	72.9	91.7	50.1	20.4	98.8	83.3	73.9	26.8
2-CUE	CFI	.02	.04	.02	.16	.11	.01	.03	.02	.05	.05
MODE	PAR	75.4	97.6	72.4	90.4	44.6	19.6	98.8	83.0	72.7	27.6
	%HIQUAL	87.6	82.7	53.2	71.6	94.2	39.9	100	31.8	70.1	25.7
3-CUE	CFI	.02	.03	.05	.05	.02	.07	.02	.25	.06	.08
MODE	PAR	87.4	82.2	50.9	70.2	94.1	35.7	100	14.8	66.9	30.3

* 1800

% HIQUAL F = 0.09 DOF 2 / 21

CFI F = 0.57 DOF 2 / 21

PAR F = 1.28 DOF 2 / 21

Element 3, Segment 3 Description:

Subject was instructed to decelerate to 80 kts while maintaining 015R and 1800' altitude segment 3 began at 8 DME and terminated at 9 DME.

Element 3, Segment 3 Findings (See Tables 17, 18, 19):

Airspeed was maintained within the "highly qualified" bandwidth more frequently in the gyro mode than in the two and three-cue modes. Reduced pilot activity was found when the pitch bar was in view. The subjects were on course more frequently with the F/D roll command information available.

The higher two-cue performance over that of three cue performance can be attributed to increased activity about the roll axis in three-cue profiles. This activity might be explained by the higher collective activity recorded in the three-cue modes.

This higher collective lever activity apparently was a benefit as the three-cue altitude PAR was higher than the other two modes.

Table 17

* Airspeed

Element 3 Segment 3 Average Duration 51

SUBJECT PILOT		1	2	3	4	5	6	7	8	M	SD
GYRO MODE	%HIQUAL	93.5	74.4	92.9	79.6	97.1	97.2	75.7	87.8	87.3	9.4
	CFI	.21	.31	.41	.74	.86	.08	.61	.20	.43	.28
	PAR	92.1	66.5	89.0	64.5	94.6	97.0	60.9	85.4	81.3	14.8
	H/R	92.9	112.0	95.3	104.6	101.4	98.5	91.1	91.3	98.4	7.3
2-CUE MODE	%HIQUAL	93.6	65.6	90.7	61.4	89.2	46.0	67.7	69.4	73.0	16.7
	CFI	.19	.34	.35	.12	.50	.08	.21	.14	.24	.14
	PAR	92.4	53.9	87.5	56.8	83.8	41.8	60.1	65.1	67.7	18.2
	H/R	89.2	99.5	92.5	102.3	111.1	125.8	87.4	98.3	100.8	12.7
3-CUE MODE	%HIQUAL	89.6	75.2	59.7	81.2	50.5	81.7	41.7	55.8	66.9	17.3
	CFI	.22	.41	.20	.13	.54	.17	.21	.19	.26	.14
	PAR	87.3	65.0	51.6	78.8	23.8	78.6	29.5	47.4	57.8	23.6
	H/R	87.3	110.1	93.6	97.4	100.7	110.1	90.6	104.1	99.2	8.6

* 80 Knots

% HIQUAL F = 3.93 DOF 2 / 21

CFI F = 2.13 DOF 2 / 21

PAR F = 3.02 DOF 2 / 21

H/R F = 0.12 DOF 2 / 21

Table 18

*CDI

Element 3 Segment 3 Average Duration 51

SUBJECT PILOT		1	2	3	4	5	6	7	8	M	SD
	%HIQUAL	40.3	47.8	52.8	30.1	17.1	57.6	41.5	60.0	43.4	14.5
GYRO	CFI	.34	.54	.45	.64	.61	.45	.61	.17	.48	.16
MODE	PAR	20.0	19.6	31.6	-8.2	-33.5	38.5	5.8	53.2	23.6	16.0
	%HIQUAL	93.6	65.6	90.7	61.4	89.2	46.0	67.7	69.4	73.0	16.7
2-CUE	CFI	.20	.38	.14	.09	.43	.11	.29	.16	.23	.13
MODE	PAR	92.3	52.5	89.4	57.9	84.6	40.1	58.3	64.5	67.5	19.1
	%HIQUAL	53.0	45.4	63.2	51.3	44.8	47.8	50.2	63.1	52.4	72
3-CUE	CFI	30	.37	.40	.38	.54	.43	.59	.25	.41	.11
MODE	PAR	38.9	25.2	48.5	32.8	15.0	25.4	20.8	53.9	32.6	13.6

*R-015

% HIQUAL F = 1.79 DOF 2 / 21

CFI F = 7.37 DOF 2 / 21 **

PAR F = 12.7 DOF 2 / 21 **

** F. 995 (2/21) = 6.89

Table 19

*Altitude

Element 3 Segment 3 Average Duration 51

SUBJECT PILOT		1	2	3	4	5	6	7	8	M	SD
	%HIQUAL	55.6	92.1	57.1	79.0	100	47.5	58.8	49.7	67.5	20.2
GYRO	CFI	.02	.02	.06	.05	.10	.03	.02	.02	.04	.03
MODE	PAR	54.7	91.9	54.5	78.0	99.9	45.9	58.0	48.7	66.5	20.1
	%HIQUAL	68.2	77.9	65.0	54.3	61.5	0.0	96.9	68.0	61.5	27.9
2-CUE	CFI	.03	.02	.05	.04	.09	.03	.13	.02	.05	.04
MODE	PAR	67.6	77.5	63.3	52.5	58.0	-3	96.5	67.4	60.7	26.9
	%HIQUAL	70.0	70.2	71.1	100	91.0	10.4	100	58.7	71.4	29.1
3-CUE	CFI	.11	.04	.04	.02	.05	.02	.12	.07	.06	.04
MODE	PAR	66.7	69.0	69.9	100	90.1	8.6	99.9	55.8	70.0	29.7

* 1800 Feet

% HIQUAL F = 0.30 DOF 2 / 21

CFI F = 0.56 DOF 2 / 21

PAR F = 0.29 DOF 2 / 21

Element 3, Segment 4 Description:

Each subject was instructed to begin a climb upon reaching 9 DME. The climb was to be accomplished at 1000 feet per minute (FPM) while flying in either the gyro or two-cue modes or a 7° flight path angle (FPA) when flying in the 3-cue mode. Level off attitude was 2500 feet. The 015R was to be maintained throughout the maneuver.

Element 3, Segment 4 Findings (See Tables 20, 21, 22):

Airspeed performance was generally better in the Gyro mode than in the two or three-cue modes. The availability of the pitch command did reduce the pilot workload slightly.

The subjects were able to maintain their desired course within the highly qualified bandwidth more frequently with the roll command in view.

The climb was accomplished within bandwidths more with the third cue in view than without collective command.

Although the three-cue mean CFI was twice that of the two-cue CFI, it was still less than the Gyro mode CFI.

Table 20

* Airspeed — Element 3 Segment 4 Average Duration 76

SUBJECT	PILOT	1	2	3	4	5	6	7	8	M	SD
GYRO MODE	%HIQUAL	86.1	71.9	74.8	100	64.7	79.5	61.8	48.0	73.4	15.9
	CFI	.19	.52	.14	.45	.31	.29	.33	.05	.37	.26
	PAR	83.5	57.3	71.3	99.6	53.8	73.6	49.2	45.4	66.7	18.7
	H/R	94.7	114.6	94.3	105.2	99.1	101.7	88.8	90.2	98.6	8.5
2-CUE MODE	%HIQUAL	100	59.7	35.3	57.9	71.6	67.1	78.3	32.3	66.7	18.7
	CFI	.22	.21	.29	.21	.03	.12	.50	.10	.21	.14
	PAR	99.8	51.2	16.5	48.3	70.8	63.2	67.5	25.5	55.4	26.4
	H/R	60.2	100.6	93.6	102.2	110.8	127.3	85.4	98.3	97.3	19.4
3-CUE MODE	%HIQUAL	99.8	86.9	51.5	34.4	63.7	76.6	83.5	45.0	67.7	22.8
	CFI	.22	.24	.32	.25	.46	.28	.58	.07	.30	.16
	PAR	99.8	83.8	36.0	18.0	47.0	70.1	73.9	41.2	58.7	27.5
	H/R	87.1	111.2	96.4	98.1	98.9	110.9	83.0	102.3	98.5	10.0

* 80 Knots

% HIQUAL F = 2.39 DOF 2 / 21

CFI F = 0.84 DOF 2 / 21

PAR F = 0.45 DOF 2 / 21

H/R F = 0.02 DOF 2 / 21

Table 21

*CDI Element 3 Segment 4 Average Duration 76

SUBJECT PILOT		1	2	3	4	5	6	7	8	M	SD
	%HIQUAL	29.8	53.6	54.2	28.8	23.8	61.9	41.0	55.0	43.5	14.6
GYRO	CFI	.18	.52	.18	.44	.49	.13	.32	.17	.30	.16
MODE	PAR	17.2	29.5	46.0	-2.5	-13.5	57.0	22.1	47.4	29.4	19.0
	%HIQUAL	51.4	59.2	59.6	61.4	43.3	62.9	63.3	47.9	56.1	7.6
2-CUE	CFI	.17	.39	.29	.30	.07	.11	.33	.04	.21	.13
MODE	PAR	43.1	43.3	47.9	49.8	39.3	58.8	51.2	45.8	47.4	6.00
	%HIQUAL	55.5	56.2	61.4	63.6	49.5	61.7	57.1	63.3	58.5	4.9
3-CUE	CFI	.17	.51	.36	.29	.57	.41	.23	.31	.36	.14
MODE	PAR	47.9	33.9	47.5	53.0	20.7	46.0	47.2	51.9	41.5	12.0

* R-015

% HIQUAL F = 5.33 DOF 2 / 21 **

CFI F = 2.07 DOF 2 / 21

PAR F = 4.31 DOF 2 / 21 ***

** F .957(2/21) = 4.46

*** F .95 (2/21) - 3.47

Table 22

*VVI (FPA) Element 3 Segment 4 Average Duration 76

SUBJECT PILOT		1	2	3	4	5	6	7	8	M	SD
	%HIQUAL	35.7	18.4	22.6	25.6	71.	8.7	12.8	29.8	20.1	10.2
GYRO	CFI	.03	.03	.04	.03	.14	.06	.02	.02	.05	.04
MODE	PAR	33.8	16.0	19.5	23.4	-5.9	3.2	11.1	28.4	17.7	10.7
	%HIQUAL	51.0	22.8	16.7	15.2	17.3	14.1	6.6	22.9	24.6	15.9
2-CUE	CFI	.02	.02	.01	.03	.01	.01	.05	.01	.02	.01
MODE	PAR	50.1	21.3	15.9	12.7	16.7	13.2	1.9	22.1	19.2	14.0
	%HIQUAL	41.1	64.9	46.1	6.0	0.0	0.0	0.0	76.9	29.4	31.8
3-CUE	CFI	.05	.03	.05	.02	.03	.04	.08	.01	.04	.02
MODE	PAR	38.2	63.9	43.4	4.1	-3	-4	-8	76.7	30.2	29.6

% HIQUAL F = 0.5 DOF 2 / 21

CFI F = 1.93 DOF 2 / 21

PAR F = 0.45 DOF 2 / 21

Element 4, Segment 1 Description:

Upon completion of 3-4 and no sooner than 10 DME, subjects were tasked with a 1,000 fpm (or 7° FPA) descent to 1800'. A 180° turn was accomplished in conjunction with the descent. Segment analysis was completed at 10 DME.

Element 4, Segment 1 findings (See Tables 23, 24, 25):

Airspeed was maintained more accurately with the pitch command in view. Three-cue performance was only slightly better than that of gyro mode performance.

Roll attitude was maintained more accurately while flying with the Gyro mode display. Control activity remained about the same when two or three-cue displays were added but performance greatly deteriorated. Since the subjects were tracking the command properly, it can only be assumed that the command was not properly calibrated for the desired 15° angle of bank.

Altitude rate was more accurately maintained by flying flight path angle (three-cue). Vertical Velocity was "tracked" slightly better in the gyro mode as compared to the two-cue performance.

Table 23

* Airspeed — Element 4 Segment 1 Average Duration 104

SUBJECT	PILOT	1	2	3	4	5	6	7	8	M	SD
	%HIQUAL	85.3	73.6	83.2	ND	64.4	78.5	40.3	ND	70.9	16.8
GYRO	CFI	.15	.03	.11	ND	.13	.42	.44	ND	.21	.17
MODE	PAR	83.1	72.8	81.4	ND	59.8	69.5	14.0	ND	63.4	25.7
	H/R	93.4	114.2	93.4	ND	104.2	104.2	81.8	ND	99.6	11.1
	%HIQUAL	100	71.5	66.1	81.9	89.9	74.0	50.0	53.2	73.3	17.2
2-CUE	CFI	.22	.08	.14	.11	.60	.24	.43	.25	.26	.18
MODE	PAR	99.8	69.2	61.4	79.9	83.8	67.8	28.5	41.5	66.5	23.0
	H/R	88.8	99.2	92.6	102.4	117.6	130.4	77.4	97.9	100.8	16.6
	%HIQUAL	86.0	74.3	82.4	56.0	59.2	91.3	44.9	74.5	71.1	16.2
3-CUE	CFI	.26	.42	.16	.24	.37	.31	.08	.32	.27	.11
MODE	PAR	82.4	63.9	79.6	45.4	44.1	88.6	40.5	66.3	63.8	18.8
	H/R	88.3	107.3	95.5	98.6	97.9	113.1	85.7	104.1	98.8	9.2

* 80 Knots

% HIQUAL F = 0.05 DOF 2 / 19

CFI F = 0.25 DOF 2 / 19

PAR F = 0.04 DOF 2 / 19

H/R F = 0.07 DOF 2 / 19

Table 24

Roll Altitude *

Element 4 Segment 1 Average Duration 104

SUBJECT	PILOT	1	2	3	4	5	6	7	8	M	SD
	%HIQUAL	57.9	33.2	35.4	ND	46.3	43.8	49.5	ND	44.4	9.2
GYRO	CFI	15	.08	.33	ND	.38	.29	.41	ND	.27	.13
MODE	PAR	46.1	27.9	14.1	ND	25.9	27.5	28.8	ND	28.4	10.3
	%HIQUAL	54.2	14.8	37.2	33.6	17.7	20.3	25.5	17.4	27.6	13.4
2-CUE	CFI	.05	.17	.30	.45	.41	.33	.33	.30	.29	.13
MODE	PAR	51.9	-12.5	18.4	3.7	-16.0	-6.0	.92	-7.4	4.1	22.1
	%HIQUAL	21.1	22.9	18.7	14.4	14.1	37.3	10.0	10.1	18.6	8.9
3-CUE	CFI	.23	.36	.39	.40	.44	.24	.22	.07	.29	.12
MODE	PAR	3.0	-4.9	-13	-19.8.	-23.7	22.3	-9.8	3.8	-5.3	14.8

* 15° ANGLE OF BANK

% HIQUAL F = 9.76 DOF 2 / 19**

CFI F = 0.05 DOF 2 / 19

PAR F = 6.95 DOF 2 / 19***

**F .995 (2/19)=7.09
***F .99 (2/19)=5.93

Table 25

VVI (FPA) *

Element 4 Segment 1 Average Duration 104

SUBJECT	PILOT	1	2	3	4	5	6	7	8	M	SD
	%HIQUAL	.23	7.6	4.3	ND	5.8	5.5	6.7	ND	5.4	1.9
GYRO	CFI	.03	.01	.01	ND	.07	.06	.03	ND	.04	.03
MODE	PAR	.63	6.7	3.3	ND	-.79	.17	3.9	ND	2.5	2.6
	%HIQUAL	2.6	7.2	2.8	6.8	6.2	3.0	3.1	5.2	4.6	1.9
2-CUE	CFI	.02	.03	.02	.02	.05	.05	.04	.03	.03	.01
MODE	PAR	.65	4.4	.86	4.9	1.5	1.9	.78	2.7	2.2	1.7
	%HIQUAL	81.0	73.4	32.5	58.8	58.5	52.8	72.8	ND	61.4	16.2
3-CUE	CFI	.03	.06	.05	.04	.05	.04	.04	.04	.04	.01
MODE	PAR	80.4	71.8	29.1	57.2	56.4	50.9	71.7	ND	59.6	17.0

* 1000 fPM (-7° FPA) Descent

% HIQUAL F = 823 DOF 2 / 18**

CFI F = 1:07 DOF 2 / 18

PAR F = 76.5 DOF 2 / 18**

**F .995 (2/18) = 7.21

Element 4, Segment 2, Description:

Element 4 Segment 2 required a deceleration to 55 kts. Constant heading and altitude was to maintain throughout this segment. Segment began at 10 DME and was terminated at 9 DME.

Element 4, Segment 2 Findings (See Tables 26, 27, 28):

The pitch command was an aid in airspeed control in this segment. The three-cue configuration resulted in the lowest pilot cyclic control activity.

Heading control was also aided by the F/D system with the three-cue PAR being higher than either the gyro or two-cue PAR's.

Altitude was maintained closer with two-cue configuration displays. Three-cue performance also represented a significant improvement over gyro mode performances. Subjects were only "on" the command 63% of the time during this segment.

Table 26

Airspeed * Element 4 Segment 2 Average Duration 68

SUBJECT PILOT		1	2	3	4	5	6	7	8	M	SD
GYRO MODE	%HIQUAL	0.0	53.0	90.0	0.0	64.6	64.0	98.3	73.2	55.4	37.1
	CFI	.30	.21	.22	.22	.65	.25	.17	.22	.28	.15
	PAR	-30	43.1	87.8	-22	41.6	55.0	98.0	67.3	55.6	27.0
	H/R	96.1	114.4	88.5	104.8	63.8	102.2	85.9	90.6	93.3	15.2
2-CUE MODE	%HIQUAL	96.7	74.0	1.00	0.0	100	78.2	60.0	100	76.1	34.2
	CFI	.29	.33	.02	.48	.53	.19	.28	.20	.31	.13
	PAR	95.7	65.4	1.00	-48	99.5	74.1	49.1	99.8	70.0	22.8
	H/R	92.1	101.9	89.3	101.7	112.4	125.2	81.2	97.3	100.1	13.8
3-CUE MODE	%HIQUAL	99.3	71.0	53.4	86.3	34.8	27.5	54.5	87.2	64.3	26.0
	CFI	.06	.19	.22	.07	.41	.25	.07	.18	.18	.12
	PAR	99.3	65.6	43.2	85.3	8.1	9.4	51.3	84.9	55.9	34.5
	H/R	86.4	110.4	96.0	97.9	105.7	113.2	83.5	105.1	99.8	10.8

* 55 Knots

% HIQUAL F = 0.8 DOF 2 / 21

CFI F = 1.4 DOF 2 / 21

PAR F = 0.6 DOF 2 / 21

H/R F = 0.66 DOF 2 / 21

Table 27

Element 4 Segment 2 Average Duration 68

Heading *

SUBJECT PILOT		1	2	3	4	5	6	7	8	M	SD
	%HIQUAL	62.1	98.5	90.9	66.8	76.7	89.1	93.8	54.6	79.1	16.4
GYRO	CFI	.12	.08	.38	.47	.50	.37	.55	.16	.33	.18
MODE	PAR	57.6	98.4	87.4	51.2	65.1	85.1	90.4	47.3	72.8	19.8
	%HIQUAL	100	66.8	93.0	96.9	79.7	56.8	96.9	96.3	85.8	16.3
2-CUE	CFI	.29	.50	.38	.50	.11	.36	.58	.44	.40	.15
MODE	PAR	99.7	50.2	90.3	95.4	77.5	41.3	95.1	94.7	80.5	22.6
	%HIQUAL	98.1	100	99.0	93.4	83.7	90.3	78.7	100	91.9	8.2
3-CUE	CFI	.25	.30	.46	.39	.52	.40	.45	.20	.36	.11
MODE	PAR	97.6	99.7	98.5	90.9	75.2	86.4	69.1	99.8	89.7	11.9

* 195°

% HIQUAL F = 1.92 DOF 2 / 21

CFI F = 0.4 DOF 2 / 21

PAR F = 1.64 DOF 2 / 21

Table 28

Element 4 Segment 2 Average Duration 68

Altitude *

SUBJECT PILOT		1	2	3	4	5	6	7	8	M	SD
	%HIQUAL	60.4	100	100	13.9	12.4	40.7	17.2	53.7	49.8	35.9
GYRO	CFI	.04	.12	.01	.02	.08	.01	.04	.04	.05	.04
MODE	PAR	58.8	99.9	100	12.2	5.4	40.1	13.9	51.9	48.0	38.0
	%HIQUAL	56.5	100	36.8	81.9	80.1	69.2	75.9	34.8	66.9	22.8
2-CUE	CFI	.08	.05	.02	.06	.04	.02	.03	.13	.05	.04
MODE	PAR	53.0	100	35.5	80.8	79.3	68.6	75.2	26.3	64.8	24.8
	%HIQUAL	92.1	100	60.4	78.9	68.8	0.0	100	0.0	62.5	41.0
3-CUE	CFI	.03	.02	.03	.04	.09	.16	.03	.16	.07	.06
MODE	PAR	91.9	100	59.2	78.1	66.0	−16	100	-16	60.9	31.3

* 1800 Feet

% HIQUAL F = 0.54 DOF 2 / 21

CFI F = 0.61 DOF 2 / 21

PAR F = 0.41 DOF 2 / 21

Element 5, Segment 1 Description:

At 9 DME each subject was instructed to start a 55 knot left climbing turn at 1000 fpm (10° FPA) back up to 2500 feet. A turn to heading 015° was also performed during the climb. Segment ended when subjects were established on heading and altitude.

Element 5, Segment 1 Findings (See Table 29, 30, 31):

Airspeed performance was slightly better in the Gyro mode with only a very slight reduction of pitot cyclic pitch activity being realized when the three-cue profile was flown.

The roll altitude performance was significantly improved by the three-cue configuration. A reduction in pilot cyclic roll activity was also evident in the three-cue configuration.

The climb was also considerably improved by three-cue displays. Two-cue performance and activity were also slightly improved over that of the gyro mode.

Table 29

Element 5 Segment 1 Average Duration 88

Airspeed *

SUBJECT	PILOT	1	2	3	4	5	6	7	8	M	SD
GYRO MODE	%HIQUAL	82.0	55.9	82.9	81.9	54.9	80.0	31.0	67.6	67.1	18.7
	CFI	.44	.26	.36	.50	.40	.36	.49	.31	.39	.08
	PAR	74.1	44.4	76.7	77.9	36.9	73.9	-2.8	57.6	55.5	26.4
	H/R	93.4	111.4	92.1	106.3	104.6	101.7	80.1	95.1	98.1	9.9
2-CUE MODE	%HIQUAL	83.5	50.5	64.1	51.0	69.6	89.1	46.1	54.7	63.6	16.0
	CFI	.16	.60	.46	.31	.45	.55	.36	.21	.39	.16
	PAR	80.9	20.8	47.6	35.8	55.9	83.1	26.7	45.2	49.5	23.0
	H/R	59.9	100.8	94.4	102.6	111.6	136.8	84.3	98.1	98.5	21.9
3-CUE MODE	%HIQUAL	80.3	64.2	40.9	85.0	71.3	61.8	47.8	77.8	66.1	15.7
	CFI	.16	.50	.35	.20	.48	.50	.49	.31	.37	.14
	PAR	77.2	46.3	20.2	82.0	57.5	42.1	22.2	70.9	52.3	23.8
	H/R	89.3	109.5	98.2	99.7	102.2	110.7	83.1	103.3	94.5	9.4

* 55 Knots

% HIQUAL F = 0.09 DOF 2 / 21

CFI F = 0.04 DOF 2 / 21

PAR F = 0.08 DOF 2 / 21

H/R F = 0.02 DOF 2 / 21

Table 30

Roll Altitude * Element 5 Segment 1 Average Duration 88

SUBJECT	PILOT	1	2	3	4	5	6	7	8	M	SD
	%HIQUAL	68.0	63.8	68.0	58.9	55.0	77.5	38.2	23.0	56.6	17.8
GYRO	CFI	.31	.11	.25	.43	.38	.20	.39	.17	.28	.12
MODE	PAR	58.1	59.8	60.0	41.2	37.9	73.0	14.1	9.9	44.3	22.8
	%HIQUAL	71.2	79.9	41.2	50.2	66.3	64.6	39.5	69.1	60.3	14.8
2-CUE	CFI	.03	.43	.12	.32	.50	.31	.48	.31	.31	.17
MODE	PAR	70.4	71.3	34.1	34.3	49.5	53.6	10.5	59.8	48.0	20.1
	%HIQUAL	74.9	43.6	68.7	71.9	78.6	76.9	65.6	69.5	68.7	11.0
3-CUE	CFI	.07	.04	.44	.28	.22	.41	.32	.27	.26	.14
MODE	PAR	73.1	41.3	54.9	64.0	73.9	67.4	54.6	61.3	61.3	10.9

* 15° Angle of Bank

% HIQUAL F = 1.42 DOF 2 / 21

CFI F = 0.31 DOF 2 / 21

PAR F = 1.81 DOF 2 / 21

Table 31

VVI (FPA) * Element 5 Segment 1 Average Duration 88

SUBJECT	PILOT	1	2	3	4	5	6	7	8	M	SD
	%HIQUAL	6.5	4.1	8.0	11.1	1.8	3.3	5.9	8.9	6.2	3.1
GYRO	CFI	.06	.04	.01	.04	.02	.07	.08	.03	.04	.02
MODE	PAR	.89	-.3	7.1	7.5	.16	-3.5	-1.7	6.2	3.4	3.1
	%HIQUAL	0.0	3.6	5.6	9.7	7.7	11.9	9.8	6.0	6.8	3.8
2-CUE	CFI	.03	.06	.02	.01	.02	.02	.01	.07	.03	.02
MODE	PAR	-3	-2.0	3.7	8.8	5.9	10.1	8.9	-.58	5.4	3.6
	%HIQUAL	67.9	18.1	52.7	0.0	0.0	0.0	50.0	0.0	23.6	28.7
3-CUE	CFI	.04	.06	.02	.03	.04	.04	.02	.06	.04	.02
MODE	PAR	66.6	13.2	51.8	-3	-4	-4	49.0	-6	24.7	26.4

* 1000 FPM (+10° FPA) Climb

% HIQUAL F = 2.76 DOF 2 / 21

CFI F = 0.86 DOF 2 / 21

PAR F = 2.55 DOF 2 / 21

Element 6, Segment 3 Description:

Element 6, segment 3 was begun at 5 DME and concluded at TACAN Station passage. Subjects were maintaining the 350R inbound at 90 kts and 1800 feet. This represented the initial and intermediate phase of the non-precision approach.

Element 6, Segment 3 findings (See Tables 32, 33, 34):

Airspeed performance was best in the gyro mode configuration. The two-cue performance and activity was much worse than either gyro or three-cue profiles.

Course was maintained better with the flight director roll command in view.

Altitude performance was best in the two-cue profiles. Although three-cue performance was better than the gyro configuration, the subjects were "off" the command approximately 21% of the time. This would explain the poorer performance when compared to two-cue data.

Table 32

Airspeed * Element 6 Segment 3 Average Duration 206

SUBJECT PILOT		1	2	3	4	5	6	7	8	M	SD
GYRO MODE	%HIQUAL	74.7	65.9	62.2	42.5	85.0	46.4	45.3	33.1	56.9	17.9
	CFI	.40	.44	.09	.35	.65	.16	.44	.43	.37	.18
	PAR	64.6	50.9	58.8	22.4	75.3	37.9	21.2	4.3	41.9	24.6
	H/R										
2-CUE MODE	%HIQUAL	62.3	61.3	43.6	38.1	61.8	39.7	52.2	39.9	49.9	10.8
	CFI	.35	.18	.46	.43	.82	.56	.34	.39	.44	.19
	PAR	49.1	54.3	17.7	11.5	30.5	5.9	36.0	16.5	27.7	17.8
	H/R										
3-CUE MODE	%HIQUAL	48.0	73.3	62.0	44.0	61.7	52.5	46.1	42.9	53.8	10.8
	CFI	.19	.52	.30	.36	.58	.28	.30	.23	.35	.14
	PAR	38.1	59.4	50.6	20.2	39.5	39.2	29.9	29.8	38.3	12.4
	H/R										

* 90 Knots

% HIQUAL F = 0.54 DOF 2 / 21

CFI F = 0.70 DOF 2 / 21

PAR F = 1.23 DOF 2 / 21

H/R F = ____ DOF ____ / ____

Table 33

CDI *

Element 6 Segment 3 Average Duration 206

SUBJECT	PILOT	1	2	3	4	5	6	7	8	M	SD
	%HIQUAL	9.1	40.0	35.1	55.6	47.0	46.4	36.0	39.9	37.4	14.0
GYRO	CFI	.06	.46	.40	.58	.56	.54	.13	.33	.38	.20
MODE	PAR	3.7	12.4	9.1	29.9	17.3	17.5	27.7	20.1	17.2	8.9
	%HIQUAL	19.7	49.6	13.3	57.3	46.0	61.3	55.7	57.5	45.1	18.3
2-CUE	CFI	.36	.53	.02	.24	.33	.32	.40	.40	.32	.15
MODE	PAR	-9.2	22.9	11.6	47.1	28.2	49.0	40.5	40.5	31.0	15.4
	%HIQUAL	33.3	53.7	53.8	59.2	52.7	50.3	52.1	50.1	46.9	9.8
3-CUE	CFI	.27	.27	.38	.39	.58	.20	.42	.26	.35	.12
MODE	PAR	15.3	41.2	36.2	43.3	25.3	40.4	32.0	37.1	33.9	9.4

* R-170

% HIQUAL F = 1.49 DOF 2 / 21

CFI F = 0.30 DOF 2 / 21

PAR F = 3.11 DOF 2 / 21

Table 34

Element 6 Segment 3 Average Duration 206

Altitude *

SUBJECT	PILOT	1	2	3	4	5	6	7	8	M	SD
	%HIQUAL	75.2	77.2	53.3	72.4	27.1	33.2	75.1	92.4	63.2	23.1
GYRO	CFI	.04	.04	.02	.03	.04	.05	.04	.17	.05	.05
MODE	PAR	74.2	76.3	52.4	71.6	24.2	29.9	74.1	91.1	61.7	23.9
	%HIQUAL	86.3	72.7	76.2	79.7	66.8	79.1	91.6	75.2	78.5	7.8
2-CUE	CFI	.08	.05	.01	.05	.02	.03	.11	.01	.05	.04
MODE	PAR	85.2	71.3	76.2	78.7	66.2	78.5	90.7	75.0	77.7	7.7
	%HIQUAL	56.0	100	79.7	100	58.7	53.9	79.5	23.1	68.9	26.1
3-CUE	CFI	.03	.02	.09	.02	.06	.12	.08	.03	.06	.04
MODE	PAR	54.7	100	77.9	100	56.2	48.4	77.9	20.8	67.0	27.2

* 1800 feet

% HIQUAL F = 1.12 DOF 2 / 21

CFI F = 0.17 DOF 2 / 21

PAR F = 1.16 DOF 2 / 21

Element 7, Segment 1 Description:

The final approach course was intercepted immediately after station passage and terminated at the missed approach point (2.5 DME). A 500 fpm (3° FPA) rate of descent was utilized until reaching the minimum descent altitude. Airspeed was maintained 90 kts throughout the approach.

Element 7, Segment 1 Findings (See Tables 35, 36, 37):

A reduction in pilot activity and an increase in pilot airspeed performance was evident in the three-cue profile. However, two-cue performance was less than that of the gyro mode.

F/D display was an aid to the pilot in his navigation task as both performance and activity were improved in the F/D modes over that of the gyro mode.

Once again, by using the collective command, the subjects were able to maintain the climb criteria closer than when flying vertical velocity.

Element 7, Segment 2 Description:

Table 35

Airspeed *

Element 7 Segment 1 Average Duration 102

SUBJECT	PILOT	1	2	3	4	5	6	7	8	M	SD
	%HIQUAL	20.8	40.3	49.7	67.0	65.9	41.2	84.7	58.2	53.5	19.8
GYRO	CFI	.30	.37	.28	.51	.59	.55	.40	.48	.44	.12
MODE	PAR	-3.0	18.2	35.6	50.2	45.8	8.9	78.6	38.1	34.8	24.6
	H/R	93.5	113.2	89.5	103.1	78.4	62.8	62.5	92.7	87.0	18.1
	%HIQUAL	33.6	54.3	59.4	53.4	40.5	39.9	56.9	36.3	46.8	10.2
2-CUE	CFI	.21	.60	.41	.34	.67	.57	.63	.48	.49	.16
MODE	PAR	19.7	26.9	42.8	37.6	.64	5.6	29.8	5.7	21.01	15.8
	H/R	94.2	96.1	90.5	99.7	110.1	131.3	61.0	99.1	97.7	19.6
	%HIQUAL	64.4	49.8	75.3	58.0	68.7	14.5	61.8	41.5	54.3	19.2
3-CUE	CFI	.21	.48	.18	.39	.38	.22	.49	.36	.34	.12
MODE	PAR	56.9	25.7	70.9	41.6	56.8	-4.3	43.1	20.4	40.0	22.0
	H/R	89.0	1.06.7	92.1	98.4	80.4	114.7	87.8	102.1	96.8	11.6

* 90 Knots

% HIQUAL F = 2.39 DOF 2 / 21

CFI F = 2.59 DOF 2 / 21

PAR F = 1.36 DOF 2 / 21

H/R F = 0.99 DOF 2 / 21

Table 36

*CDI

Element 7 Segment 1 Average Duration 102

SUBJECT PILOT		1	2	3	4	5	6	7	8	M	SD
	%HIQUAL	20.3	30.7	0.0	13.4	9.1	21.7	32.8	22.2	18.8	10.9
GYRO	CFI	.35	.38	.32	.47	.37	.33	.29	.35	.36	.05
MODE	PAR	-7.6	4.4	-32	-27.3	-24.5	-4.1	13.3	-5.0	14.8	11.5
	%HIQUAL	39.9	45.3	7.6	28.9	45.2	7.4	37.3	27.3	29.9	15.3
2-CUE	CFI	.36	.33	.39	.39	.19	.47	.48	.45	.38	.09
MODE	PAR	18.3	27.3	-28.4	1.2	34.8	-36.1	7.2	-5.4	19.8	13.8
	%HIQUAL	38.9	21.1	20.0	21.9	39.4	33.5	22.5	38.8	29.5	8.9
3-CUE	CFI	.37	.43	.27	.42	.44	.40	.17	.27	.35	.10
MODE	PAR	16.3	-12.8	-1.6	-10.9	12.7	6.9	9.3	22.3	11.6	6.2

*R 140

% HIQUAL F = 2.20 DOF 2 / 21

CFI F = 0.39 DOF 2 / 22

PAR F = 1.79 DOF 2 / 22

Table 37

*VVI(FPA)

Element 7 Segment 1 Average Duration 102

SUBJECT PILOT		1	2	3	4	5	6	7	8	M	SD
	%HIQUAL	5.5	6.8	4.7	5.1	7.9	30.4	2.3	4.8	8.4	9.0
GYRO	CFI	.04	.02	.03	.02	.02	.02	.02	.04	.03	.01
MODE	PAR	1.7	4.9	1.8	3.2	6.1	29.0	.4	1.0	6.0	9.5
	%HIQUAL	6.7	5.0	6.1	5.3	5.2	6.6	5.9	4.2	5.6	.9
2-CUE	CFI	.02	.02	.09	.04	.07	.06	.11	.14	.07	.04
MODE	PAR	4.8	3.1	-2.4	1.5	-1.4	1.0	-4.5	-9.2	3.5	2.7
	%HIQUAL	84.5	88.5	64.8	60.4	89.2	53.9	85.7	82.4	76.2	14.1
3-CUE	CFI	.04	.06	.07	.07	.02	.07	.03	.05	.05	.02
MODE	PAR	83.9	87.8	62.3	57.6	89.0	50.7	85.3	81.5	74.8	15.3

*1000 fpm (-3° FPA) Descent

% HIQUAL F = 0.39 DOF 2 / 21

CFI F = 4.74 DOF 2 / 21

PAR F = 121.7 DOF 2 / 21**

**F.995 (2/21) = 6.89

Element 7 segment 2 consisted of a 500 fpm (4° FPA) climbing left turn back up to 1800 feet. The missed approach heading was 050°. Element analysis was concluded at 4 DME. A 90 kts missed approach airspeed was used during this maneuver.

Element 7, Segment 2 Findings (See Tables 38, 39, 39A):

Airspeed was slightly improved by the flight director pitch bar. Pilot cyclic pitch activity was lowest in the three-cue profile.

Roll attitude was greatly improved during three-cue profiles. Two-cue roll attitude was slightly improved over gyro performance. The difference between three-cue and the Gyro/Two-cue performance might be explained by addition of the third cue for altitude control.

The missed approach climb was maintained better by using FPA (three-cue) as opposed to vertical velocity. Pilot activity was also slightly lower during the three-cue profile. This reduced activity might be a result of the reduced activity associated with the cyclic pitch control activity mentioned above.

Table 38

Element 7 Segment 2 Average Duration 93

Airspeed *

SUBJECT PILOT		1	2	3	4	5	6	7	8	M	SD
	%HIQUAL	58.0	48.9	37.8	76.2	65.4	71.8	30.8	44.8	54.2	16.3
GYRO MODE	CFI	.19	.63	.26	.18	.15	.18	.55	.23	.30	.20
	PAR	50.0	16.7	21.6	71.9	60.2	66.7	-7.3	32.1	37.6	22.3
	H/R	93.9	109.9	84.9	102.0	92.0	99.8	75.3	83.2	92.6	11.3
	%HIQUAL	59.7	52.4	25.3	46.6	48.0	84.1	44.8	48.4	51.2	16.5
2-CUE MODE	CFI	.06	.42	.16	.26	.36	.64	.13	.45	.31	19.3
	PAR	57.3	32.4	13.4	32.7	29.3	73.9	37.6	25.2	37.7	19.1
	H/R	59.0	99.6	89.0	100.0	103.5	132.6	78.9	95.1	95.3	22.4
	%HIQUAL	67.3	81.2	19.3	20.1	60.7	27.5	77.4	42.6	49.5	25.4
3-CUE MODE	CFI	.17	.23	.01	.31	.46	.31	.44	.15	.26	.15
	PAR	61.7	76.9	18.5	-4.7	42.6	5.0	67.5	34.0	38.9	28.2
	H/R	73.2	109.8	91.1	99.3	105.9	75.5	84.0	101.0	92.5	13.8

* 90 Knots

% HIQUAL F = 0.11 DOF 2 / 21

CFI F = 0.17 DOF 2 / 21

PAR F = 0.01 DOF 2 / 21

H/R F = 0.05 DOF 2 / 21

Table 39

VVI * Element 7 Segment 2 Average Duration 93

SUBJECT PILOT		1	2	3	4	5	6	7	8	M	S
	%HIQUAL	8.8	11.5	8.9	10.8	7.6	7.3	9.8	12.2	9.6	1.
GYRO	CFI	.03	.03	.06	.02	.01	.05	.14	.02	.05	.0
MODE	PAR	6.6	8.9	3.4	10.8	.67	2.7	-2.8	10.4	6.5	3.
	%HIQUAL	7.7	9.2	9.2	9.0	8.6	12.4	12.8	11.1	10.0	1.
2-CUE	CFI	.06	.01	.02	.08	.04	.04	.04	.05	.04	.0
MODE	PAR	2.2	8.3	7.4	7.2	4.9	8.9	9.3	6.7	6.9	2.
	%HIQUAL	83.1	28.6	43.0	33.5	52.9	43.5	81.7	93.0	57.4	24.
3-CUE	CFI	.01	.02	.02	.06	.02	.10	.01	.01	.03	.
MODE	PAR	82.8	27.2	41.9	29.5	52.0	37.9	81.5	92.9	55.7	26.

* 500 fPM (+4°) Climb

% HIQUAL F = 28.94 DOF 2 / 21**

CFI F = 0.39 DOF 2 / 21

PAR F = 17.21 DOF 2 / 21

** F .995 (2/21) =6.89

Table 39A

Roll Command* Element 7 Segment 2 Average Duration 93

SUBJECT PILOT		1	2	3	4	5	6	7	8	M	SD
	%HIQUAL	47.9	0.0	60.2	52.6	0.0	0.0	18.2	28.6	25.9	25.2
GYRO	CFI	.26	.47	.09	.48	.09	.45	.14	.29	.28	.17
MODE	PAR	34.4	-47	56.6	29.9	-9	-45	6.8	7.9	4.3	37.0
	%HIQUAL	22.7	15.6	60.4	25.2	39.7	64.2	0.0	14.7	30.3	22.7
2-CUE	CFI	.41	.31	.43	.17	.64	.15	.29	.53	.37	.17
MODE	PAR	-9.0	-10.6	43.4	12.5	1.1	58.8	-29	-30.5	4.6	32.3
	%HIQUAL	35.6	100.0	33.3	17.3	3.3	21.1	64.8	22.2	37.2	31.1
3-CUE	CFI	.08	.13	.18	.36	.21	.21	.59	.19	.24	.16
MODE	PAR	30.5	99.9	21.3	-12.5	-17.0	4.5	44.0	7.4	22.3	37.5

* 15° Angle of Bank

% HIQUAL F = 0.37 DOF 2 / 21

CFI F = 1.13 DOF 2 / 21

PAR F = 0.66 DOF 2 / 21

Element 8, Segment 1 Description:

The ILS approach analysis was begun when localizer was within 1/4 dot of center and concluded when decision height was reached on the radar altimeter. A 90° kts, 3° Glide Slope was maintained throughout. During the two-cue profile the ILS was flown twice, once with Glide Slope being maintained by use of the collective and the second time with glide slope being tracked with cyclic pitch and through the pitch control. The second ILS is identified by element number 9.

Element 8, Segment 1 findings (Tables 40, 41, 42):

Airspeed performance was improved by the addition of the F/D with the 3-cue performance activity ratio slightly higher than the two-cue PAR. Pilot cyclic pitch activity was also lowest during the three-cue ILS approaches.

The pilots ability to track the ILS Localizer was improved by the F/D in that both two and three-cue PAR's are higher than the gyro mode performance. Two-cue performance was the highest as was the pilot cyclic roll activity.

Glide slope performance was significantly improved in the two-cue profiles. Gyro mode and three-cue data was almost identical with three-cue performance, only one percent higher than gyro performance. The addition of collective activity to the performance figures further reduces the slight margin maintained by the three-cue system. It must be noted that the subjects were "on" the collective command only 47.3% (mean) of the time during the ILS approach.

Table 40

Airspeed * Element 8 Segment 1 Average Duration 167

SUBJECT PILOT		1	2	3	4	5	6	7	8	M	SD
	%HIQUAL	99.0	9.0	72.1	64.5	76.4	ND	34.4	52.4	58.3	29.6
GYRO	CFI	.18	.51	.27	.42	.49	ND	.47	.51	.41	.13
MODE	PAR	98.8	-37.4	64.6	49.6	64.8	ND	3.6	28.1	49.6	30.6
	H/R	60.1	110.0	85.3	58.3	63.7	ND	78.2	92.9	69.8	35.3
	%HIQUAL	94.6	63.8	75.9	73.0	50.2	65.1	59.2	ND	68.8	14.2
2-CUE	CFI	.41	.12	.20	.66	.38	.52	.46	ND	.39	.18
MODE	PAR	92.4	59.5	71.1	55.2	31.3	47.0	40.4	ND	56.7	20.4
	H/R	80.2	83.2	98.0	108.0	105.1	99.4	90.6	ND	94.9	10.6
	%HIQUAL	93.9	71.4	68.5	41.9	85.3	66.4	54.8	68.0	68.8	16.2
3-CUE	CFI	.44	.56	.11	.14	.52	.29	.31	.42	.35	.17
MODE	PAR	91.2	55.4	65.0	33.8	77.7	56.7	40.8	54.6	59.4	18.6
	H/R	66.9	73.3	90.4	96.5	97.3	74.9	92.9	ND	81.7	12.6

* 90 Knots

% HIQUAL F = 0.61 DOF 2 / 19

CFI F = 0.27 DOF 2 / 19

PAR F = 1.00 DOF 2 / 19

H/R F = 2.30 DOF 2 / 18

Table 41

Localizer *

Element 8 Segment 1 Average Duration 167

SUBJECT PILOT		1	2	3	4	5	6	7	8	M	SD
	%HIQUAL	13.6	28.9	83.9	84.7	37.6	ND	34.4	97.1	54.2	33.3
GYRO	CFI	.28	.35	.01	.61	.53	ND	.49	.13	.34	.22
MODE	PAR	-10.6	4.0	83.7	75.4	4.5	ND	.77	96.7	39.4	43.5
							ND				
	%HIQUAL	98.4	81.3	21.3	99.7	14.4	48.9	50.4	ND	59.2	34.9
2-CUE	CFI	.52	.05	.37	.57	.51	.27	.61	ND	.41	.21
MODE	PAR	97.6	80.4	-7.8	99.5	29.3	35.1	20.1	ND	52.8	38.5
	%HIQUAL	91.0	60.0	57.0	54.7	10.3	31.1	67.8	40.0	51.5	24.5
3-CUE	CFI	.40	.61	.31	.29	.41	.10	.40	.28	.35	.15
MODE	PAR	87.4	35.6	43.7	41.6	-26.5	24.2	54.9	23.2	42.1	21.3

* 140°

% HIQUAL F = 0.12 DOF 2 / 19

CFI F = 0.31 DOF 2 / 19

PAR F = 0.32 DOF 2 / 19

Table 42

GLIDE SLope *

Element 8 Segment 1 Average Duration 167

SUBJECT PILOT		1	2	3	4	5	6	7	8	M	SD
	%HIQUAL	25.1	15.1	8.6	18.6	14.9	ND	15.6	30.5	18.3	7.3
GYRO	CFI	.01	.06	.05	.02	.02	ND	.03	.05	.03	.02
MODE	PAR	24.4	10.5	.40	17.0	13.2	ND	13.1	27.0	15.1	8.9
	%HIQUAL	19.1	28.6	28.9	39.0	28.3	28.1	43.1	ND	30.7	7.9
2-CUE	CFI	.03	.01	.04	.03	.02	.01	.02	ND	.02	.01
MODE	PAR	16.7	27.9	26.1	37.2	26.9	27.4	42.0	ND	29.2	8.2
	%HIQUAL	17.0	21.1	10.6	20.8	12.4	12.3	40.9	19.3	19.3	9.6
3-CUE	CFI	.07	.08	.02	.02	.05	.06	.04	.07	.05	.02
MODE	PAR	11.2	14.8	8.8	19.2	8.0	7.0	38.5	13.7	15.2	10.3

*3°

% HIQUAL F = 4.78 DOF 2 / 19*

CFI F = 4.43 DOF 2 / 19**

PAR F = 5.53 DOF 2 / 19*

** F .975 (2/19) =4.56

*** F .95 (2/19/ = 3.52

Element 8, Segment 2 Description:

Element 8, segment 2 represents the missed approach phase of the ILS. Instructions were identical to that of the non-precision missed approach (Element 7, segment 2). Recording was terminated after establishing missed approach heading, airspeed and altitude.

Element 8, Segment 2 findings (See Tables 43, 44, 45):

The ability to track FPA as compared to vertical velocity is once again apparent. This performance was accomplished with no real change in collective activity as all three missed approachs resulted in approximately the same CFI.

Roll attitude was best maintained while flying with gyro mode displays. Three-cue configuration provided the best F/D configuration performance.

Airspeed performance was greatly improved by the addition of the third cue. A reduction in pilot activity was also evident while flying the three-cue ILS approach.

Table 43

Airspeed * Element 8 Segment 2 Average Duration 57

SUBJECT	PILOT	1	2	3	4	5	6	7	8	M	SD
	%HIQUAL	20.4	41.7	54.9	57.1	92.7	ND	27.2	32.1	46.6	24.5
GYRO	CFI	.49	.29	.52	.42	.34	ND	.72	.55	.48	.14
MODE	PAR	18.6	24.8	31.5	39.1	90.2	ND	25.2	-5.3	33.5	27.1
	H/R	65.0	111.6	81.1	79.3	104.4	ND	78.8	73.5	84.8	16.8
	%HIQUAL	27.4	73.7	21.3	36.6	23.6	57.1	30.6	ND	38.6	19.5
2-CUE	CFI	.33	.61	.40	.45	.66	.51	.44	ND	.49	.12
MODE	PAR	3.4	57.7	-10.2	8.1	-26.8	35.2	.06	ND	20.2	20.9
	H/R	66.2	72.0	92.0	96.6	110.9	135.7	83.5	ND	93.8	23.8
	%HIQUAL	87.6	60.4	95 4	59.4	61.3	74.5	70.9	38.1	68.5	17.9
3-CUE	CFI	.22	.42	-27	.16	.46	.21	.25	.63	.33	.16
MODE	PAR	84.9	43.8	94.2	52.9	43.5	69.2	63.6	-.9	56.6	29.0
	H/R	98.7	110.1	87.8	95.7	99.9	ND	100.2	ND	98.7	7.2

* 90 Knots

% HIQUAL F = 4.23 DOF 2 / 19 **

CFI F = 2.96 DOF 2 / 19

PAR F = 4.87 DOF 2 / 19 ***

H/R F = 1.04 DOF 2 / 17

**F .95 (2/19) =3.52

***F .975 (2/19) =4.51

Table 44

Element 8 Segment 2 Average Duration 57

Roll Altitude *

SUBJECT PILOT		1	2	3	4	5	6	7	8	M	SD
	%HIQUAL	32.3	55.4	43.5	90.2	37.1	52.7	55.7	20.8	48.5	20.8
GYRO	CFI	.16	.30	.29	.40	.30	.23	.44	.37	.34	.09
MODE	PAR	21.5	42.0	27.1	86.2	18.2	41.8	36.2	-8.5	33.1	27.0
	%HIQUAL	16.4	20.9	23.1	30.2	32.3	43.2	31.8	26.8	28.1	8.3
2-CUE	CFI	.20	.54	.22	.43	.46	.53	.28	.18	.36	.15
MODE	PAR	-.32	-21.8	6.2	0.2	1.16	13.1	12.7	13.6	3.11	11.7
	%HIQUAL	45.0	28.1	29.9	44.8	33.6	64.3	28.5	21.5	34.6	17.8
3-CUE	CFI	.30	.14	.59	.23	.28	.21	.32	.31	.30	.13
MODE	PAR	28.5	18.0	-11.5	32.1	15.0	56.8	5.6	-2.8	17.7	21.6

* 15° Angle of Bank

% HIQUAL F = 3.62 DOF 2 / 21 **

CFI F = 0.44 DOF 2 / 21 **

PAR F = 4.03 DOF 2 / 21

** F .95 (2/21) = 3.47

Table 45

Element 8 Segment 2 Average Duration 57

VVI (FPA) *

SUBJECT PILOT		1	2	3	4	5	6	7	8	M	SD
	%HIQUAL	15.2	11.4	19.8	9.6	10.7	ND	11.5	11.6	12.8	3.5
GYRO	CFI	.02	.03	.04	.06	.07	ND	.07	.06	.05	.02
MODE	PAR	13.5	8.7	16.6	4.2	4.5	ND	5.3	6.3	8.4	4.8
	%HIQUAL	11.0	11.6	6.5	17.0	11.4	8.6	13.7	ND	11.4	3.4
2-CUE	CFI	.02	.05	.06	.02	.05	.02	.03	ND	.04	.02
MODE	PAR	9.2	7.2	.9	15.3	7.0	6.8	11.1	ND	8.2	4.4
	%HIQUAL	100.0	27.3	100.0	32.7	100.0	ND	ND	32.8	65.5	37.9
3-CUE	CFI	.06	.05	.08	.03	.02	.11	.02	.05	.05	.03
MODE	PAR	99.9	23.7	99.9	30.7	100	ND	ND	29.4	63.9	39.5

* 500 fpm (+4° FPA) Climb

% HIQUAL F = 13.89 DOF 2 / 17 **

CFI F = 1.03 DOF 2 / 19

PAR F = 13.69 DOF 2 / 17**

** F .995 (2/10) = 7.35

Element 9, Segment 1 Description:

A two-cue ILS was flown identical to that described in Element 8, Segment 1. The only change to this approach was that the pilot was instructed to maintain glide slope with cyclic pitch inputs and use collective to maintain airspeed. The pitch command was used to track glide slope deviations.

Element 9, Segment 1 findings:

Only two subjects were able to obtain any highly qualified time at all during this approach. Typical performance began with subject "pushing over" at the glide slope intercept point. This was followed, a few moments later by an increase in airspeed. Pilot properly responded to increased airspeed with a reduction in collective. While this helped reduce airspeed it also caused the aircraft to go below glide slope. The pilots would then apply aft cyclic to reestablish position on glide slope. The natural result of such a maneuver would be a rapid reduction in airspeed since power had just reduced collective to compensate for a higher than desired airspeed. The application of collective, at this point, had the opposite effect than that desired by the pilot. Instead of increasing airspeed, a reduction or no increase in airspeed resulted because of the cyclic pitch input (aft) previously made to climb back to glide slope. The subjects would now instinctively increase collective to obtain an increase in airspeed and this would, of course, worsen the situation. By now the aircraft was usually well above glide slope and the pilot would apply forward cyclic to "dive" back on glide slope. The combination of an extreme nose low attitude and high power setting would soon combine to place the aircraft, once again, below glide slope and high on airspeed. The cycle would begin again with ever increasing magnitude of both power and cyclic pitch inputs.

Glide slope intercept was approximately four miles from the runway. All eight subjects encountered the same situation described above and, depending upon winds and pilot technique, all had gone divergent by two miles from touchdown. These pilots induced oscilliations would usually be on the order of $\pm 20°$ pitch changes from the ninety knot attitude. Worse cases would result in pitch attitude going from plus 30° to a minus 30° attitude in a twenty second period on final.

Element 9, Segment 2 Description:

The missed approach instructions were identical to those of 7-2 and 8-2. Upon going into the missed approach mode, the pitch bar reverted from glide slope to airspeed and the subject then initiated a climb with application of collective.

Element 9, Segment 2 findings:

The missed approach was equally unsuccessful in that, again, only two subjects were able to establish highly qualified bandwidths in any parameter.

B. SUBJECTIVE DATA FINDINGS

Each subject was provided with a questionnaire to be completed at specific times during the data collection process. These times were just prior to familiarization flights (preflight questionnaire), at completion of each data flight (Gyro, Two-cue, Three-cue) and upon completion of final flight (post project questionnaire). The collated questionnaire responses are contained in Attachments "A" through "E".

The general flight experience level of the subject pilots used in this study is atypical of the Air Force helicopter population in that most had flown fixed wing as well as rotary wing aircraft. Their total experience, instructor flying time and actual instrument time are also well above the "average" Air Force helicopter pilot.

The total impact of an increased experience factor on the data was anticipated during the pre-experimental phase of the project. It was decided that if even slight differences between the modes were found, then, these differences should be considered valid, since it can be assumed that basic instrument flying (Gyro-Mode) performance would be better than that of "typical" Air Force helicopter pilots. Additionally, it is reasonable to assume that a F/D system would benefit most an inexperienced instrument pilot because he has not yet fully developed the techniques of good basic instrument flying. Ease of the instrument cross-check is also greatly simplified by use of a flight director.

The experience factor also affected the general "tone" of the subjective data gathered from the subject pilots. This was due to the fact that it may be harder to overcome the natural tendencies to maintain the system in the most familiar Gryo mode.

The basic design of the questionnaires was directed toward detecting opinion shifts from mode to mode as well as validating the merit of supporting displays.

The pertinent pilot comments were recorded during the data flights. These comments reflected the effects of learning on pilot acceptance. That is to say, the more flights with the system the more favorable the pilot comments.

Pre Flight Questionnaire Findings (See Attachment "A"):

As previously mentioned, subject pilot experience was well above that of the average USAF Helicopter pilot. Subjects three and five were the only pilots lacking fixed wing or previous F/D system experience.

The most general anticipated advantage of the F/D system was the ease of instrument cross-check with resultant reduced workload. Specific areas, of improvement that most subjects anticipated were improved ILS performance, simplified missed approach execution and the assistance provided in intercepting and maintaining courses.

The specific disadvantage anticipated by most subjects were fixation on command information at the expense of raw data, degraded airspeed control at higher airspeeds, and high pilot workload associated with "setting-up" the F/D systems.

When asked to comment about the method used to display the collective command, six subjects thought system would be satisfactory while two expressed no opinion.

In response to the question about preference for either ILS approach configuration "A" or "B", most subjects (6) preferred the "A" configuration. The remaining two subjects favored the "B" configuration because it was similar to what they flew in fixed wing Flight Director ILS approaches. The final question asked was for any changes they would like to make to the flight director controls or displays, however, only two responses were received. One subject (8) felt the FPA slew should be placed on the collective lever since this is the flight control used to adjust FPA. The other response (subject 2) addressed the desirability of non-linear gain changes to the pitch command so that at high airspeed the amount of command displacement for a given error would be less than the amount of the same error at a lower airspeed.

Gyro Questionnaire (See Attachment "B"):

Seven of the eight subjects found that the glide slope displayed in the ADI and the localizer displayed in the HSI posed no problems. The only complaint mentioned was directed at the increased difficulty of instrument cross-check and subject seven described this as only a "minor" problem.

The relocation of the turn-and-slip indicator to the ADI was reported as an improvement by four subjects. Three subjects did not like this change simply because of the reduced size of the turn-and-slip indicator.

When asked to address the utility of the entire instrument panel the most common complaint among the subject pilots was aimed at the separation between the power instruments and the flight instruments. Four subjects made this observation but in reality the physical separation between these two groups of instruments was the same in the test bed helicopter as the conventional TH1F instrument panel.

None of the eight subjects felt that the gyro mode displays improved performance or reduced workload enough to warrant single pilot IMC operation.

When asked if the expanded ADI pitch scale was an asset or detriment to their performance, five subjects reported it detrimental, two said there was an improvement and one felt it had no effect.

The use of airspeed and heading "markers" was a definite improvement according to five of the subjects. Three felt the markers were not an aid primarily because of the requirement to slew the markers to desired heading or airspeed.

The following Cooper-Harper mean ratings and standard deviations were obtained from the eight subjects:

Airspeed Control - 4.25 mean/.71 standard deviation
Altitude Control - 3.36 mean/.92 standard deviation

Two-Cue Mode Questionnaire (See Attachment "C")

The acceptance of the Go-around mode was rated as a very useful feature by all eight subjects. Additional comments such as "outstanding,"

"best feature", etc. were included.

When asked about the suitability of the pitch command for those maneuvers which requires accelerating or decelerating while maintaining altitude the subjects' comments varied. General acceptance of the pitch command was evident; however a caution toward the possibility of over controlling was mentioned.

The majority of the subjects (six) found that the mode annunciator provided the required information concerning the F/D mode status. All found it to be appropriately located and a suitable attention getting device during mode changes.

When asked about problems with either interpreting or satisfying the pitch and roll commands, the only problems noted were associated with trying to satisfy the pitch command during the configuration "B" ILS approach. Roll command was judged slightly better than pitch command for ease of satisfying the command.

The Radar Altitude display (digital) was judged "excellent" by all eight subjects.

All eight subjects preferred the "A" configuration for ILS approaches. The following Cooper-Harper rating adequately reflects this finding:

	Mean	Standard Deviation
Airspeed Control(Configuration "A")	2.38	.52
Airspeed Control (Configuration "B")	7.80	3.01
Glide Slope Control (Congiguration "A")	2.63	.52
Glide Slope Control (Configuration "B")	7.88	3.09

Two-cue and Three-Cue airspeed, heading, and attitude control ratings for segments other than ILS approaches were found to be improved over the Gyromode ratings. Attitude control remained nearly identical to gyro mode ratings.

	Mean	Standard Deviation
Airspeed Control (Gyro mode)	3.25	1.58
Heading Control (Gyro mode)	3.38	.92
Attitude Control (Gyro mode)	2.63	.52

Inflight comments supported the postflight Cooper Harper ratings awarded the configuration "B" ILS approaches. Totally "unsatisfactory" was the typical response.

Three-cue Mode Questionnaire (See Attachment "D"):

As in the two-cue flights, the mode annunciator, go-around mode, pitch command and Radar Altitude/FPA display were judged excellent by all subjects.

The third-cue collective command was judged to be too sensitive by several subjects, but not to the degree that it was a major problem. Most subjects felt it was easy to follow and that it provided an improvement. There was a trend toward slightly higher collective command ratings in the ILS mode where it was used to maintain glide slope as opposed to the maneuvers where it was employed to maintain FPA.

When used to maintain altitude, the collective command was identified as being "sluggish" by several subjects. However, the majority of subjects found it to be satisfactory.

All eight subjects felt that the concept of using FPA in helicopters was very realistic. The location of the FPA/Altitude Hold switch posed some minor problems for two subjects. Their objection was not due to the fact that it was located on the collective lever but that it was placed in an awkward position for them.

The following Cooper Harper rating means and standard deviations resulted from the three-cue flights.

	Mean	Standard Deviation
Airspeed Control (Three-Cue mode)	2.38	.74
Altitude Control (Three-Cue mode)	3.75	1.28
Heading Control (Three-cue mode)	2.38	.58

Post Project Questionnaire (See Attachment "E")

The anticipated advantages of the F/D system mentioned in the pre-flight questionnaire were generally the same as those identified as being realized in the post project questionnaire.

The difficulties addressed in the post project questionnaire include those concerned with the configuration "B" ILS approach and the excessive dependence on commands at the expense of "Raw Data" information.

When asked to comment on the method of displaying collective command only one subject did not like the display. He (subject 5) expressed a desire for a quantitative display such as torque.

Five of the subjects stated that they were sufficiently confident at the end of their approximate five hours of experience with the F/D system to fly in IMC. Two stated that they needed further training and one said he would not fly the H-1 in weather without a stability augumentation system.

Only one of the subjects felt that he would not want the F/D system flown in this study installed in his aircraft. He felt that current instrumentation (H-1N) was completly adequate and that the addition of the F/D system would not be cost effective. Two subjects wanted the F/D system without the third cue as they felt it was too sensitive.

The eight subjects generally agreed that the digital radar altitude display increments were satisfactory. The only change recommended was to extend the readout in 10 foot increments when below 300 feet. Current logic calls for 20 foot increments when below 300 feet and above 100 feet. At 100 feet the display changed every 10 feet.

When asked if the addition of the flight director warranted reduction of the current Air Force H-1 minimum instrument airspeed of 70 knots, only one subject said "yes." The remaining seven said "no" and added that stability augmentation system would be required in order to safely operate in IMC below 70 knots.

The effect of the various modes on pilot workload was identified by the subjects as follows

Highest Workload -	Gyro	(4 Subjects)
	Two-Cue	(2 Subjects)
	Three-Cue	(2 Subjects)
Lowest Workload -	Gyro	(2 Subjects)
	Two-Cue	(3 Subjects)
	Three-Cue	(3 Subjects)

The difference between two-cue and three-cue flight director suitability, performance and workload was identified by the general dislike of the two-cue mode because of its effect on the instrument cross-check. The problem with tracking the "bars" and then trying to cross-check the altimeter was cited as the main discrepancy. Six of the subjects favored the three-cue system over the two-cue. Two subjects preferred the two-cue over the three-cue system. Subjects are asked to comment about any problems associated with the requirement to use a 15° angle of bank to satisfy the roll command. Only one subject felt this was a problem. The resultant turn rates at lower airspeed (55 knots) was the source of his complaint.

C. HEARTRATE AND HEARTRATE VARIABILITY

Incomplete data reduction makes findings in this area unassessable at this time, but an explanation of expected results should be informative to those interested.

Increases in mean heartrate correlated with increases in workload have been noted in some past studies involving flying tasks. Since workload is difficult to define empirically and some mental processing tasks evidence decreases of heartrate, the heartrate variability measure has been developed and used by some investigators to study the confounding effects. Tasks that require a centralized type of mental processing may be expected to stabilize heartrate, therefore decreasing variability. Tasks requiring more peripheral visual scanning and mental processing of multi-cue information may be expected to show greater levels of variability. A general task analysis of Gyro procedures and processing would show flying in the Gyro Mode to require more peripheral visual activity and multi-cue processing which would be reflected in higher rate variability. Three-cue heartrates might be expected to be less variable because of the centralized attention to the Flight Director Command Bars.

In the segment-by-segment analysis of heartrates and variability, the expectations stated above may be confounded by the subtle differences between processing information for maneuvering the aircraft and the constant need to monitor instruments concerning engine performance, and to perform safety and communications tasks.

URINALYSIS

Analysis of urine samples for all biochemical measures has not been completed at the time of this writing. 17 OHCS analysis procedures are being changed due to safety precautions and could not be reported until standardization is accomplished.

Other biochemical measures were completed recently, but statistical analysis is not finished at this time. A preliminary analysis of the available biochemical indicators appears to show no trends by which to differentiate the modes of flight. Although in nearly every case (except NE levels on the 3-cue flights) average values of biochemical indicators for all subjects are greater for any of the flights than for non-flying baseline periods; there is no consistent order or magnitude of change from baseline among the 5 variables, Urea, E, NE, Na and K. Na/K ratio decreased from baseline levels for all flights but order and magnitude of change followed no significant trend. See figure 11.

SLEEP AND FATIGUE

Subjects averaged 7.5 hours sleep the night before their flights and baseline days. Sleep periods ranged from 5.5 to 11 hours and most of the time subjects responded that they were moderately to well rested. While they usually responded that they could use more sleep, there appears to be no intervening effects from sleep loss or illness.

BIOCHEMICAL ANALYSIS OF URINARY CONSTITUENTS

Each value represents a mean[a] for eight subjects and is expressed per 100mg Creatinine.

MODE	UERA (mg)	NE (mg)	E (mg)	NA (mEq)	K (mEq)	NA/K (Ratio)
GYRO	1347	6.779	2.485	14.136	7.665	2.29
2-Cue	1326	9.405	3.020	14.32	5.709	2.83
3-Cue	1438	3.190[b]	2.355[b]	15.65	8.06	2.43
BASELINE	1300	5.364	2.204	13.03	4.92	3.09

[a] Baseline is mean of three samples per subject. Post flight samples are one per subject for each mode.

[b] One subject's samples unreadable.

FIGURE 11

SUBJECTIVE FATIGUE SCORES

(Means from 8 Subjects for flights and baseline days)

	PRE	POST[a]	% CHANGE
GYRO	12.3	8.8	-28
2-Cue	11.1	10.3	-7
3-Cue	11.9	10.0	-15
BASELINE[b]	13.1	11.7	-10

[a] Post scores for flights are average of two scores collected after TACAN missed approach and after ILS.

[b] Baseline is mean of 3 scores per subject for pre and post flight.

FIGURE 12

Subjective fatigue levels reported after Gyro flights were significantly higner than those reported after the other flights or baseline non-flying periods. The mean level of 8.8 for Gyro compared to 10.3 for 2 Cue, 10.0 for 3 Cue and 11.7 for baseline is significant at the .012 level. This final score reflects a greater decrease from the preflight report (3.5 units or approximately, 28%) when compared to 2-Cue (0.8 units, 7%); 3-Cue (1.9 units, 15%); and Baseline (1.4 units, 10%) for pre to post changes. See figure 12.

Subjective fatigue checkcards have been sensitive in past studies to work and stress and have agreed with circadian variations in urine and temperature indications. In this case, Subjective Fatigue differentiates the Gyro flight mode from the other flight modes by indicating mild fatigue compared to little or no fatigue from the other modes. This result leads us to look for greater elevations in urine indicators for Gyro, which is not the case. Higher mean heartrates could also be expected in the Gyro mode, but heartrate data is incomplete and that which is available does not show systematic differences.

SECTION IV

CONCLUSIONS

A. ROLL COMMAND

As described in Section I, the F/D system incorporated a multi-function roll command with the capability to maintain selected heading, course, or Roll Attitude (15° ANGLE OF BANK).

When the F/D System was used as an aid to maintain selected heading, the roll command proved to be superior to the Gyro mode heading marker.

The percentage of highly qualified Heading Performance time was greater while flying with the Two and Three-cue system than that of the gyro mode. By collapsing the five elements which included as a pilot task, maintaining heading, the following means and standard deviations resulted: Gyro mode 76.7/9.7, Two-cue Mode 82.7/9.2, Three-cue Mode 83.6/7.3. In addition, pilot activity was highest during the Gyro Mode profiles with the lowest activity occurring during the Three-cue profiles.

When tasked with maintaining a course or localizer during the ILS approach, using the F/D system the pilots again achieved superior performances with reduced workloads. The collapsed data from seven common segments provided the following performance means and standard deviations: Gyro Mode 38.8/10.1, Two-cue 52.4/13.6 Three-cue 49.4/10.9. The Two-cue mode provided very slight advantage over Three-cue Mode performance. Pilot activity was the highest in the Gyro Mode. Two-cue and Three-cue pilot activity was identical.

The ability to maintain Roll Attitude was not generally enhanced by the Flight Director Roll Command. Since roll attitude performance was inconsistent between elements, no real conclusions can be made about F/D performance vs non-F/D performance.

The Subjective data supports the finding of the analysis of the objective data; that is, the Roll Command was generally the most acceptable of the three F/D system commands.

B. PITCH COMMAND

As mentioned previously the pitch command was to establish and maintain desired airspeed during the Two and Three-cue profiles. The Two-cue (configuration "B") ILS profile was the only exception to the pitch command use for airspeed control and will be covered in detail in paragraphs to follow in this section of the report.

The analysis of data addresses the maintaining of airspeed only and does not address the acceleration or deceleration aspects within the various segments.

All subjects were tasked with holding discrete airspeeds of 55 knots, 80 knots, 90 knots, or 100 knots. After analyzing the objective data by airspeed groupings, it was very evident that, the best airspeed performance was obtained at 80 knots regardless of configuration. The second best performance was obtained during maneuvers at 55 knots followed by 90 knots. The maneuvers demonstrating the poorest performance occurred when holding 100 knots. The following PAR's represent the collapsed data for all subjects across airspeed groupings.

55 knot:	Gyro/51.7	Two-cue/54.0	Three-cue/54.0	Mean/53.2
80 knot:	Gyro/69.5	Two-cue/59.7	Three-cue/57.7	Mean/62.3
90 knot:	Gyro/35.5	Two-cue/28.0	Three-cue/45.5	Mean/36.3
100 knot:	Gyro/35.5	Two-cue/26.0	Three-cue/30.7	Mean/29.2

Cyclic pitch activity was lowest while flying in the Three-cue configuration at all airspeeds. Activity for the Two-cue and Gyro configurations was nearly identical at all airspeeds. The addition of the pitch bar did not appear to greatly effect airspeed performance, however, it did reduce pilot activity when flown in a three-cue configuration. The activity reduction could be attributed to the pilots' ability to identify and correct airspeed errors sooner in the three-cue configuration than in the two-cue display configuration. By not requiring the pilot to look at both the altimeter and the vertical velocity indicator while using the Three-cue mode his attention can be maintained on the attitude indicator.

The subjective data generally supports the premise that the pilots preferred the Three-cue configuration over both the Gyro and the Two-cue mode displays. However, the subjects did comment about the sensitivity of the pitch command. The fact that the attitude indicator horizon would move behind the pitch bar was falsely interpreted as a pitch command display movement. Although the movement was noted and incorrectly diagnosed as an overly sensitive pitch command, the Subjects did not move the cyclic pitch in an effort to "chase" the movement. They correctly tracked the pitch bar and as a result they obtained lower CFI scores.

C. COLLECTIVE COMMAND:

As with the roll command, the collective command is a multi-function display. Subjects were tasked with maintaining either level altitude, FPA climbs and descents or glide slope.

When tasked with maintaining altitude, the subjects performed better with the collective command (three-cue) in view than without the command (i.e., gyro and two-cue). The Gyro Mode PAR was 64.8%, Two-cue was 65.1% and Three-cue was 69.1%. The subjects were able to attain this improved performance with almost the same CFI. A.04 CFI for Gyro and the two-cue mode was recorded as compared to a .05 CFI for the three-cue mode.

When the subjects were asked to climb or descend by use of the Vertical Velocity Indicator in the Gyro and Two-cue prifiles or Flight Path Angle in the Three-cue profiles, the data shows a clear advantage while flying in a Three-cue configuration. The following PAR's resulted: Gyro/16.0, Two-cue/8.2, Three-cue/37.3.

Pilot activity (CFI) was again only very slightly higher (.03 vs .04) while tracking the collective command. The subjects quickly learned that the best way to "fly" the collective command was to make a collective input and then wait for the input to take effect. Unlike the Roll or Pitch Commands, vertical rate has no predictive value, therefore, it will only be "zeroed" when desired Flight Path Angle is reached. It was obvious that the sooner the subjects identified this technique the better they flew the profile. When using the command for holding altitude, the command could be kept "zeroed" at all times.

The Glide Slope control recorded during the Three-cue ILS approaches was slightly worse than that of the Gyro mode performance (i.e., 15.9 PAR vs 15.3 PAR). A PAR of 29.3 was recorded for the Two-cue ILS (configuration "A"). When looking at the subjects ability to keep the command "zeroed", the problem became obvious that the subjects were tracking on the command less than 50% of the approach.

This problem is also noted in the subjective data from comments concerning the sensitivity of the collective command on the ILS approaches. The sensitivity problem was most apparent during the final portion of the approach where gain changing was accomplished in the F/D system computer program. A change in the program was initiated by the use of a radar altitude signal.

These gains appeared to be too sensitive since increased pilot activity resulted in poorer pilot tracking and reduced actual glide slope performance.

D. ILS CONFIGURATION "B" APPROACH:

Based on both subjective and objective data, this approach proved to be totally unsatisfactory.

As discussed in the Findings Section, all subjects went divergent on the controls and found the approach totally unflyable. If the requirement to maintain airspeed had not been required, then the approach would have been "flyable". However, the operational application would be questionable without considering a specific airspeed. Furthermore, any F/D system logic should be consistent throughout. In other words, it would have been procedurally unwise to fly a non-precision approach with pitch controlling airspeed and collective controlling altitude and then reverse these control functions when flying an ILS approach. Several subjects identified this problem when using the missed approach feature of the F/D system. After flying the ILS's with glide slope on the pitch bar and airspeed maintained by collective inputs, going missed approach in effect, reversed control functions. Pitch, now controlled airspeed, and Collective reverted to altitude control. The confusion was obvious.

E. FLIGHT DIRECTOR MODE vs GYRO MODE

The addition of the F/D system represented an improvement which is supported in both the subjective and objective data. A general improvement in performance and a reduction in pilot control inputs was observed when flying with F/D commands in view. The subjects felt that the system provided a definite advantage over their existing instrumentation.

As previously discussed, the nature of the subject pilots' high experience level makes both subjective and objective data findings particularly noteworthy.

Although most subjects had flown F/D systems before, none had ever flown a Helicopter System and, therefore, used the control performance concept (i.e., Pitch-Airspeed and Collective-Altitude) in its purest sense. They all were more "comfortable" in the Gyro mode yet still favored adoption of a flight director system. All felt that the system, as flown, did not warrant single pilot IMC operation, in that inherent workload was still too high. The requirement for aircraft stability remains the prime request for single pilot IFR operation.

F. TWO-CUE VS THREE CUE CONFIGURATIONS

Although Two and Three-cue performance was almost identical, any differences usually favored Three-cue performance. The added versatility of the FPA System and continuing requirement to fly a system which provides electronic guidance in the vertical plane. (i.e., ILS, Tactical Approach Systems, Global Positioning System, and the Area Navigation concepts all combine to make the Three-cue system the optimum system. Subjective data also shows a definite preference for the Three-cue system over the Two-cue displays.

The anticipated problem with "splitting" the pilot's cross-check during the Two-cue flights did not materialize. Original concern was aimed at the possiblity of degraded vertical control performance by requiring the pilot to fly a mix of flight director commands and cross checking the conventional altimeter and vertical velocity displays. It is apparent that the subjects did not have a problem.

With the combination of both subjective and objective data it becomes apparent that, while not as desirable as the Three-Cue system, the two-cue system represents a distinct improvement over the conventional displays.

G. SUPPORTING DISPLAYS AND SYSTEMS

The use of a digital readout to present radar altitude was judged to be an excellent concept. This is particularly true in flying a F/D because of the tendency to reduce the area of instrument cross-check. The use of red incondescent light segments proved to pose no problem with "washing-out" during the day or dimming for night flights.

The location of various slewable markers (heading and airspeed) and positioning of control switches was found to be acceptable with the possible exception of the Flight Path Angle Slew switch and "Altitude Hold/FPA" selector switch.

In the case of the slew switch it would be better located on the collective lever instead of the present location on the pilots cyclic grip. The switch used to select either Altitude Hold or FPA inputs to the collective command is presently located just below the head of the collective lever. A more suitable location would be on the top of the collective lever. The present switches are of the strain-gauge type and, therefore, prove difficult to slew. Since switches are located on the cyclic stick, the pressure required to engage the slew coupler would also result in cyclic stick movement. A replacement switch of the ordinary mechanical variety would be more suitable.

The need to move power instruments closer to the flight instrument displays was evident. Although instrument location is basically unaltered, the tendency to limit the cross-check area makes confirmation of power and rotor speeds more difficult.

Operation of the flight director controller would be improved by replacing the rotory switches with push-button type switching. Optimum location of the controller would be on the instrument panel.

H. PSYCHOPHYSIOLOGICAL AND BIOCHEMICAL DATA CONCLUSIONS

Further analysis of heartrate and Biochemical data by more sophisicated statistical methods, presently being accomplished, may lead to some changes from this preliminary assessment; but it appears that subjective fatigue is the only indicator which differentiates one mode of flight from the others. Although it is a subjectively reported measure, it has ageeed well with physiological effects in past studies. It appears that the pilots perceived some greater physiological cost from the procedures required to fly the Gyro mode, but the stress or strain of these procedures were insufficient to activate systematic increases in urinary variables measured by our tests. It seems likely that the short duration missions (less than one hour) and the minor changes among the instruments indications and characteristics were within the subjects' ability to adapt. The general increase in urinary levels over baseline is expected with any flying mission.

A more comprehensive understanding of the task-by-task adaptation to the differences in instrumentation may be available in the ECG data which will be reported after completion in a technical report from USAFSAM along with statistical findings regarding urinary constituents.

SECTION V

RECOMMENDATIONS:

1. Air Force Helicopter acquisition should include a Flight Director System in the Flight Instrumentation system with the following recommendations:

a. Three-cue configuration preferable over a Two-cue configuration.
b. Current control performance concepts (ref. AFM 51-37) for helicopters should be incorporated in the F/D logic (i.e., pitch controls airspeed and collective controls altitude).
c. Use of tape instruments be included in order to provide peripheral information on performance of critical systems such as engines, rotor speed and power indicators.
d. Digital information on altitude, preferably radar altitude, be provided as close to attitude indicator as possible.
e. Control of Flight Director System should enable pilots to keep hands on primary Flight Control while making inputs to the system.

2. Retrofit of existing Air Force H-1 fleet should only be accomplished if existing mission is changed to include a substantial increase in IMC operation.

3. Retrofit of existing H-3, H-53 helicopters should be considered since a Flight Director, when used in conjunction with currently installed stability systems, would provide an ideal IFR system.

4. Single pilot IMC operation based on the addition of a Flight Director System is not recommended for Air Force H-1 helicopters. Single pilot operation of H3, H53 helicopters should be based on further studies.

5. Further studies be conducted to:

a. Establish use of low airspeed system with omni-sensing capability for use in instrument take-off maneuvers. This includes optimum displays to provide lateral movement indications.
b. Determine the validity of a rotor plane based Gyro System for input to both attitude and heading gyros.
c. Determine utility of Flight Director command information displayed in a Heads-up Display (HUD) system
d. Determine the utility of a combined command depicting both Roll and Pitch command information in one symbol. This information to be displayed either Heads-up on a HUD or Heads-down on conventional F/D system.

HELICOPTER FLIGHT DIRECTOR

PREFLIGHT QUESTIONNAIRE

Subject Number 1 thru 8 Date 28/01/77 thru 22/03/77

Operational mission normally flown: Training, VIP Support, Rescue

Aircraft/helicopter current in: H-3, H1-N, TH-1F

Please indicate your flight experience (approx):

	Average	Min.	Max.
Total flying time as pilot	2,922	1,700	6,000
Total helicopter time	1,725	'800	2,800
Total instructor pilot time	1,069	58	4,000
Total actual instrument time	82	30	200
Total simulated instrument time	325	200	600
Estimated total hours flown with a flight director	430	0	1,000
Fixed Wing total time	1,197	0	4,000

1. What advantages, if any, do you feel the current flight director offers for flying basic instrument maneuvers? improved crosscheck- better airspeed control- reduced workload- single pilot operation- increased flexibility by use of FPA- precise pitch control

2. What advantages, if any, do you feel the current flight director offers for terminal area navigation and instrument approaches? excellent for ILS approaches- easier to preform missed approach- another verification of performance data- capability to slow on final approach- assist on course intercepts

3. What difficulties, if any, do you feel may be encountered using the current flight director for flying basic instrument maneuvers? tendency not to check "raw data"- airspeed control at higher airspeeds- workload associated with setting up the F/D- takes engine instruments out of crosscheck

4. What difficulties, if any, do you feel may be encountered using the current flight director for terminal area navigation and instrument approaches? system does not allow for exchanging airspeed for altitude

ATTACHMENT A

5. Do you feel that the method of displaying collective lever command is satisfactory? If no, why not?

need more graphic "up" and "down" markers- six said yes and two said they had no opinion

6. Which ILS two-cue approach configuration do you think you would prefer: configuration 'A' (pitch = airspeed) or 'B' (pitch = glide slope)? Please comment.

six subjects favored "A" and 2 subjects favored "B" - reason for selecting "B" was because that is the way fixed wing flight directors are programmed on ILS approaches -

7. Please identify any additions or deletions you would make to the existing flight director controls/displays.

think the FPA slew switch should be placed on collective lever- pitch command should change gains as a function of airspeed-

HELICOPTER FLIGHT DIRECTOR

GYRO MODE PROFILE QUESTIONNAIRE

Subject Number__________________________Date_______________

1. Did having the glide slope display on the ADI and localizer display on the HSI cause you any problems?

   NO=seven subjects, YES=one subject (considered a minor problem)

2. Has the addition of the turn and slip indicator to the ADI helped in maintaining coordinated flight?

   YES=four subjects, NO=three subjects (not large enough)

3. With the RAD ALT marker set on DH, was the light noticeable when you reached the DH altitude?

   YES=six subjects, NO=one subject- one subject stated that he saw the light but that he felt it was not obvious enough, "perhaps a audio tone would be more desirable"

4. What did you like about the arrangement of the instrument panel?

   DME in HSI- Radar Altitude display- ADI/HSI location

5. What did you dislike about the arrangement of the instrument panel?

   four subjects noted that the power instruments were out of the normal cross-check- one subject disliked the fact that the whole panel is offset to the left

6. Did you find the RADAR ALT digital display to be useful?

   YES=six subjects, NO=one subject, one subject had no opinion

7. Do you feel the gyro mode displays unburden the pilot enough to warrant single pilot IMC operations in the H-1?

   All eight subjects said NO, one qualified his no by saying that if a radio operator was added he would say yes. Another said that if a stability system were added then gyro displays would then be satisfactory.

ATTACHMENT B

8. Did you find expanded pitch to be an asset or detriment to your instrument flying?

One subject found no difference, two claimed it was an asset and the remaining five found it to be a deteriment.

9. Were the slewable airspeed and heading markers an aid to your instrument flying?

YES=five subjects, NO=three subjects- the subject that did not find them an aid stated that their objection was to the amount of time envolved in slewing them to the desired airspeed or heading.

10. Using the attached "Cooper-Harper" rating scale, rate the following parameters while flying in the gyro mode:

SUBJECT NO.	1	2	3	4	5	6	7	8	mean/std dev
Airspeed control:	4	4	5	4	3	5	5	4	4.25/.71
Altitude control:	4	3	5	3	2	3	3	4	3.36/.92
Heading control:	4	4	5	4	5	6	5	5	4.75/.71

ADEQUACY FOR SELECTED TASK OR REQUIRED OPERATION	CONTROL/DISPLAY CHARACTERISTICS	DEMANDS ON THE PILOT IN SELECTED TASK OR REQUIRED OPERATION	PILOT RATING
Is it satisfactory without improvement — Yes	Excellent Highly desirable	Pilot compensation not a factor for desired performance	1
	Good Negligible deficiencies	Pilot compensation not a factor for desired performance	2
	Fair -- Some mildly Unpleasant deficiencies	Minimal pilot compensation required for desired performance	3
No — Deficiencies warrant improvement	Minor but annoying deficiencies	Desired performance requires moderate pilot compensation	4
	Moderately objectionable deficiencies	Adequate performance requires considerable pilot compensation	5
	Very objectionable but tolerable deficiencies	Adequate performance requires extensive pilot compensation	6
Is adequate performance attainable with a tolerable pilot workload — Yes (to "Is it satisfactory without improvement"); No — Deficiencies require improvement	Major deficiencies	Adequate performance not attainable with maximum tolerable pilot compensation. Controllability not in question	7
	Major deficiencies	Considerable pilot compensation is required for control	8
	Major deficiencies	Intense pilot compensation is required to retain control	9
Pilot decisions → Is it controllable? — Yes (to "Is adequate performance attainable with a tolerable pilot workload"); No — Improvement mandatory	Major deficiencies	Control will be lost during some portion of required operation	10

HELICOPTER FLIGHT DIRECTOR

TWO-CUE PROFILE QUESTIONNAIRE

Subject Number____________________Date__________________

1. Did you find the go-around mode to be a useful feature of the helicopter flight director?

   All eight subjects said 'YES'. "outstanding-"best feature of system"

2. Please comment on the suitability of pitch command for those maneuvers requiring acceleration or deceleration.

   "abrupt but controllable- ok, decel. better than accel.- quite useful- more suited for this maneuver than holding airspeed"

3. Did the mode annunciator properly display the information you needed to operate the flight director system?

   all eight subjects said 'YES'

4. Did the pitch and bank steering bars present useful information?

   "pitch command wandweed too much- bank steering most useful- prefer bank over pitch" all eight subjects said 'YES'

5. Did you have any problems in interpreting and/or satisfying the pitch and bank steering commands? If yes, explain.

   "confused pitch command with artificial horizon a couple of times- hard to hold ± 5 knots with pitch command"

6. Please comment on the following uses of the roll command (e.g., sensitivity, suitability, display, etc.), for:

Selecting and maintaining heading: "difficult at 55 Knots- excellent- great- superer- did not like slew"

Interpret, roll out and maintaining course: "easy to follow- best feature of F/D system- easy to fly- overly sensitive at station passage"

ATTACHMENT C

ILS approaches: "Excellent"

7. Did you use the radar altitude digital display for your ILS approaches? Comments.

All eight said 'YES' "would have missed DH if it were not for the display - excellent for cross-checking - used it for entire flight."

8. Which ILS approach configuration do you prefer - 'A' (pitch = airspeed) or 'B' (pitch = glide slope)?

All eight subjects preferred 'A' " 'B' is unsafe - 'A' and only 'A' - 'B' is useless - 'B' is not a natural way to fly"

9. Do you feel the two-cue displays unburden the pilot enough to warrant single pilot IMC operation?

Five said 'NO', one subject said 'YES' and two said that it required stabilization of some kind. "not with an unstabilized aircraft - do not feel comfortable with system yet - pitch attitude too sensitive."

10. Using the attached "Cooper-Harper" rating scale, rate the following parameters while flying in the two-cue mode.

	SUBJECT 1	2	3	4	5	6	7	8	mean	std dev
Airspeed control on ILS configuration 'A':	2	2	2	2	3	2	3	3	2.38	.52
Glide slope control on ILS configuration 'A':	2	3	2	3	3	2	3	3	2.63	.52
Airspeed control on ILS configuration 'B':	10	3	10	8	9	9	10	3	7.8	3.01
Glide slope control on ILS configuration 'B':	10	3	10	9	9	10	9	2	7.88	3.09

SUBJECT

	1	2	3	4	5	6	7	8	mean	std dev
Airspeed control (other than ILS):	3	3	3	2	3	7	2	3	3.25	1.58
Altitude control (other than ILS):	3	3	3	4	3	5	2	4	3.38	.92
Heading control:	2	3	2	3	3	3	3	2	2.63	.52

HELICOPTER FLIGHT DIRECTOR

THREE-CUE PROFILE QUESTIONNAIRE

Subject Number____________________Date________________

1. Did the mode annunciator properly display the information you needed to operate the flight director system?

   Seven subjects said 'YES' and one said he "never paid any attention to it".

2. Did you find the go-around mode to be a useful feature of the helicopter flight director?

   All eight subjects said 'YES'. "most useful feature- excellent- get you into the turn and climb sooner than in gyro mode or two-cue mode"

3. Please commend on the suitability of pitch command for those maneuvers requiring acceleration or deceleration.

   " abrupt- helped a lot- appears to require an excessive amount of pitch- able to maintain good control"

4. Did you find the FPA and RAD ALT digital displays to be useful?

   All subjects said 'YES'

5. Please commend on the following parameters of the collective command (e.g., sensitivity, suitability, display).

FPA: **"overly sensitive- easy to follow and see need for corrections- jumps around too much- very good- great application for helicopters"**

Glide Slope: **"felt like I was chasing command- slow to follow raw data- great- much better than flying raw data"**

ATTACHMENT D

Altitude Hold: "seemed sluggish but it was very eye catching- hard to follow at 55 knots- good except in rough air- used for trend but still had verticle velocity in my cross check"

Level Offs: " a little abrupt for 1,000 fpm climbs- ok in climb but a problem in descent level offs- no problem-good because you can not make cyclic only level offs-

6. Is flightpath angle a valid concept for helicopter?
All eight subjects said 'YES'

7. Did the location and operation of the altitude hold/FPA switch pose any problems?
"Yes, I had to look for switch every time- would be better on top of collective- needs to be bigger

8. Using the attached "Cooper-Harper" rating scale, rate the following parameters while flying in the three-cue mode:

SUBJECT	1	2	3	4	5	6	7	8	mean	std dev
Airspeed control:	2	2	2	2	2	2	2	4	2.38	.74
Altitude control:	3	4	3	4	5	3	2	6	3.75	1.28
Heading control:	2	2	2	2	2	2	3	2	2.38	.52

HELICOPTER FLIGHT DIRECTOR

POST PROJECT QUESTIONNAIRE

Subject Number______________________Date____________________

1. What advantages, if any, did the current flight director give in flying basic instrument maneuvers?

"improved performance- improved cross check- lets pilot relax- see small deviations much sooner- can fly better"

2. What advantages, if any, did the current flight director give to terminal area navigation and instrument approaches?

"do not have to worry about intercepting courses with the proper lead point- no techniques required to fly good approaches- don't have to worry about wind corrections"

3. What difficulties, if any, did you encounter when using the current flight director for flying basic instrument maneuvers?

" none after a few flights- mixed up the pitch bar with artifical horz.- collective command too sensitive"

4. What difficulties, if any, did you encounter when using the current flight director for terminal area navigation and instrument approaches?

" only problem at station passage, much too rapid imputs to the roll command- configuration 'B' ILS was worthless"

5. Do you feel that the method of displaying collective lever command was satisfactory? If no, why not?

One subject wanted a quantitative system such as torque. **The remaining seven subjects had no comments.**

ATTACHMENT E

6. Would you feel confident in flying the current flight director under IMC? If no, why not?

Five subject said 'YES' and three said 'NO'. Two subjects who said 'NO' claimed they would need more time with the system. The remaining subject said he would want a aircraft stability system.

7. Would you recommend that the current flight director be installed in USAF operational helicopter? If no, why not?

One subject said 'NO' because it would not be cost effective. Another said it would not do much good without stability for the helicopter. The two-cue system was prefered by one subject.and the remaining subjects prefered three-cue.

8. Was the RAD ALT displayed in acceptable increments? If no, please indicate desired altitude rates.

All eight said 'YES' with one wanting the scale changed to 10 foot increments when below 300 feet.

9. Does the addition of the flight director warrant a change to current -1 instrument airspeeds - currently 70K minimum with 90 knot cruise?

Only one subject said 'YES'

10. Do you feel the addition of a flight director is a significant improvement to instrument flight in the H-1?

All eight said 'YES'

11. In which of the three modes: (1) basic displays (2) two-cue flight director, (3) three-cue flight director was your workload

the highest? Four subjects said gyro, two said two-cue, two said three-cue

the lowest? Two subject said gyro, three said two-cue, three said three-cue

12. Please comment on the difference in pilot workload, performance, and general suitability of the two-cue vs three-cue flight director.

Six subjects favored three-cue and two-said they prefered two-cue. "might as well have all three cues- three-cue causes you to pump collective- more control imputs in three-cue but better performance- three-cue is better because you have to mix commands and raw data when flying two-cue"

13. Did the 15° angle of bank required to satisfy the roll command present any problems during the low speed maneuvers?

Only one subject said 'YES'. "Roll-in and Roll-out seemed too abrupt"

SLEEP SURVEY

NAME (Last, First, MI)	GRADE	DATE/TIME

1. On the chart below, mark an X in each half hour interval you slept yesterday and today.

YESTERDAY

MID-NIGHT	0100	0200	0300	0400	0500	0600	0700	0800	0900	1000	1100	1200	1300	1400	1500	1600	1700	1800	1900	2000	2100	2200	2300	MID-NIGHT

TODAY

MID-NIGHT	0100	0200	0300	0400	0500	0600	0700	0800	0900	1000	1100	1200	1300	1400	1500	1600	1700	1800	1900	2000	2100	2200	2300	MID-NIGHT

2. HOW MUCH TROUBLE DID YOU HAVE GOING TO SLEEP LAST NIGHT?

☐ NONE ☐ SLIGHT ☐ MODERATE ☐ CONSIDERABLE

3. HOW RESTED DO YOU FEEL?

☐ WELL RESTED
☐ MODERATELY RESTED ☐ SLIGHTLY RESTED ☐ NOT AT ALL

4. DO YOU FEEL LIKE YOU COULD HAVE USED SOME MORE SLEEP?

☐ YES ☐ NO

SAM FORM SEP 76 154 PREVIOUS EDITION WILL BE USED REMARKS ON REVERSE

NAME & GRADE	TIME/DATE

INSTRUCTIONS: Make one, and only one (✓) for each of the ten items. Think carefully about how you feel right now.

STATEMENT	BETTER THAN	SAME AS	WORSE THAN
1. VERY LIVELY			
2. EXTREMELY TIRED			
3. QUITE FRESH			
4. SLIGHTLY POOPED			
5. EXTREMELY PEPPY			
6. SOMEWHAT FRESH			
7. PETERED OUT			
8. VERY REFRESHED			
9. FAIRLY WELL POOPED			
10. READY TO DROP			

PREVIOUS EDITION IS OBSOLETE

SAM FORM MAY 76 136 SUBJECTIVE FATIGUE CHECKCARD

ATTACHMENT F